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Token Valuation: A Systematic Literature Review and Empirical Analysis

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Abstract

This thesis explores the challenges of token taxonomy and valuation within the rapidly evolving blockchain ecosystem. Through an extensive review of both academic and grey literature, the research identified critical gaps in the structured classification of tokens and the absence of robust valuation methodologies. A systematic review of DLT systems and token taxonomy literature was conducted, revealing significant points of convergence across different frameworks. The review provided a detailed understanding of the shared characteristics of DLT systems. Key findings underscored the complex nature of DLT systems and highlighted that token behavior is influenced by the underlying system. Moreover, the literature revealed a convergence towards three main token types: Security Tokens, Utility Tokens, and Payment Tokens. A systematic review on valuation methodologies was also coduncted and it demonstrated a notable lack of structured models, especially for DeFi tokens. While established valuation models have been applied to cryptocurrencies with revenue generation, DeFi tokens, often serving utility purposes, presented a unique valuation challenge. To bridge this gap, this thesis propose a relative valuation model, identifying key parameters for L2 solutions and DEXs, through a literature review. The empirical study focused on four L2 projects, Arbitrum, Optimism, Mantle, and Polygon. From literature review, key drivers for L2 valuation was derived. The relative valuation model was applied, with Market Capitalization per Daily Transactions (MC/TPD) selected as the key valuation multiple. Additionally, TVL was used as a companion variable. A regression analysis between MC/TPD and TVL, over a period of three months, showed a notable correlation. The parameters from literature were empirically tested through SARIMAX model. Ethereum price emerged as the strongest predictor of L2 market capitalization. This approach provided a framework for comparing projects and assessing their market positions.

Keywords: Blockchain, DLT, Token, Taxonomy, Valuation, L2, DEX, Relative Valuation

Abstract in lingua italiana

Questa tesi esplora le sfide legate alla tassonomia e alla valutazione dei token all'interno dell'ecosistema blockchain in rapida evoluzione. Attraverso una revisione approfondita sia della letteratura accademica che di quella grigia, la ricerca ha identificato lacune critiche nella classificazione dei token e l'assenza di metodologie di valutazione robuste. Una revisione sistematica dei sistemi DLT e della letteratura sulla tassonomia dei token ha rivelato punti di convergenza significativi tra diversi framework. La revisione ha fornito una comprensione dettagliata delle caratteristiche comuni dei sistemi DLT. I risultati principali hanno sottolineato la complessità dei sistemi DLT e hanno evidenziato come il comportamento dei token sia influenzato dal sistema sottostante. Inoltre, la letteratura ha mostrato una convergenza verso tre principali tipi di token: Security Tokens, Utility Tokens e Payment Tokens. Una revisione sistematica sulle metodologie di valutazione ha inoltre dimostrato una notevole carenza di modelli strutturati, in particolare per i token DeFi. Sebbene i modelli di valutazione consolidati siano stati applicati alle criptovalute con generazione di entrate, i token DeFi, che spesso svolgono funzioni di utilità, presentano una sfida unica per la valutazione. Per colmare questa lacuna, la tesi propone un modello di valutazione relativa, identificando parametri chiave per le soluzioni L2 e i DEX attraverso una revisione della letteratura. Lo studio empirico si è concentrato su quattro progetti L2: Arbitrum, Optimism, Mantle e Polygon. Dalla revisione della letteratura sono stati derivati i principali fattori di valutazione per le soluzioni L2. Il modello di valutazione relativa è stato applicato, selezionando il rapporto tra Capitalizzazione di Mercato e Transazioni Giornaliere (MC/TPD) come principale multiplo di valutazione. Inoltre, il TVL è stato utilizzato come variabile complementare. Un'analisi di regressione tra MC/TPD e TVL, su un periodo di tre mesi, ha mostrato la presenza di correlazione. I parametri derivati dalla letteratura sono stati testati empiricamente attraverso il modello SARIMAX, rivelando che il prezzo di Ethereum è emerso come il più forte predittore della capitalizzazione di mercato delle soluzioni L2. Questo approccio ha fornito un framework per confrontare i progetti e valutarne la posizione sul mercato.

Parole chiave: Blockchain, DLT, Token, Tassonomia, Valutazione, L2, DEX, Relative Valuation

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1.1. Blockchain Overview

The Blockchain landscape and the world of crypto-assets are gaining increasing relevance in today's technological and financial environment. New Blockchain projects emerge every day, designed to address and solve the challenges associated with traditional mechanisms, offering innovative solutions that push the boundaries of digital and financial possibilities. In this rapidly evolving scenario, one of the most critical aspects is the ability to provide an objective and accurate assessment of the value of these projects and the tokens associated with them.

1.1.1. The history of blockchain begins with its inception and traces its subsequent evolution

The origins of blockchain technology can be traced back to 2009, when Nakamoto (2008) published the white paper titled 'Bitcoin: A Peer-to-Peer Electronic Cash System'. In the realm of technology, a white paper is a document designed to present a new idea or an enhancement to an existing technology. Its primary purpose is to clarify the proposed innovation by outlining its advantages, potential applications, and the technological, economic, and financial implications associated with it. This document is typically intended for specialists or investors who need to carefully understand the technology before adopting it or making investment decisions.

The white paper authored by Nakamoto is widely recognized as the foundational text that catalyzed the revolution in cryptocurrencies and blockchain technology. Before its publication, the concept of a fully decentralized digital currency existed only as a theoretical idea, without concrete proof of its operational feasibility. One of the critical challenges that arose was the issue of double spending, which refers to the problem of preventing a single digital unit from being spent multiple times.

The milestone of Nakamoto's innovation was its decentralization. Unlike traditional financial systems, which rely on central authorities, Nakamoto's use of a peer-to-peer network known as 'the Blockchain' facilitated the management and execution of data and transactions without dependence on a central authority. The white paper authored by Nakamoto presented a summary of cryptographic protocols designed to validate transactions. This architecture not only improved data integrity and security but also aimed to create a decentralized system where trust and verification are distributed among all network participants, rather than being concentrated in a single entity such as a bank or government. Decentralization not only has reduced operational costs but has also eliminated the risk of a single point of failure, thereby enhancing the overall system's robustness and resilience.

The paper provided a detailed explanation of Bitcoin's mechanics and established a foundational framework that can be applied to a wide range of blockchain applications, extending beyond financial transactions to include various non-financial domains. These applications continue to evolve, driving significant advancements in security and privacy protocols. The framework described in the white paper has significantly influenced the subsequent development of blockchain technologies, facilitating progress in diverse fields such as supply chain management, healthcare, electronic voting and many others.

In particular, researchers have identified three revolutionary aspects of Nakamoto's white paper that have catalyzed the rapid wave of interest in blockchain technology: .

- **Decentralisation**: By implementing a system that removes the need for central intermediaries in transactions and their verification, it becomes possible to lower transaction costs and reduce processing times;
- **Transparency**: The blockchain ensures that every transaction is registred in an unchangeable public ledger, enhancing transparency and minimising the potential for fraudulent activities;
- **Accessibility**: Bitcoin introduced a financial system accessible to anyone globally, regardless of whether they had traditional bank accounts.

The introduction of Bitcoin, as detailed by the authors Alzhrani and Zhao (2022), marked the inception of Blockchain 1.0. This first version revolutionized the landscape by setting the way for the creation of additional cryptocurrencies and the development of new blockchain-based projects.

In 2013, Blockchain 2.0 emerged with the launch of Ethereum, which expanded blockchain technology's capabilities beyond digital currency transactions. Ethereum introduced 'smart contracts,' self-executing contracts with terms written in a programming language called Solidity. This advancement enabled more complex financial transactions beyond simple payments and transfers. It also significantly extended blockchain's potential, allowing for the creation of decentralized applications (dApps) that operate autonomously based on predefined rules.

Blockchain 3.0, which debuted in 2015, marked another significant advancement. This version introduced tokenization, a process that converts physical and intangible assets into digital tokens that can be stored and traded on a blockchain. Tokenization has opened up new paths for digital commerce and ownership, allowing tangible assets such as real estate and works of art to be represented in digital form, thus simplifying their trade and management.

In 2018, the rise of artificial intelligence led to the development of Blockchain 4.0. This iteration improved the security and efficiency of consensus protocols within blockchain systems. The integration of advanced technologies in Blockchain 4.0 enhanced the overall security, efficiency, and automation of blockchain processes, resulting in more intelligent and adaptable systems.

The latest advancement, Blockchain 5.0, emerged in 2019 with the development of Relictum Pro. This version introduced N-dimensional smart contracts, significantly increasing the practical applications of blockchain technology. Blockchain 5.0 has pushed the boundaries of the technology, offering sophisticated solutions for a wide range of applications, including the Internet of Things (IoT) and complex data and transaction management.

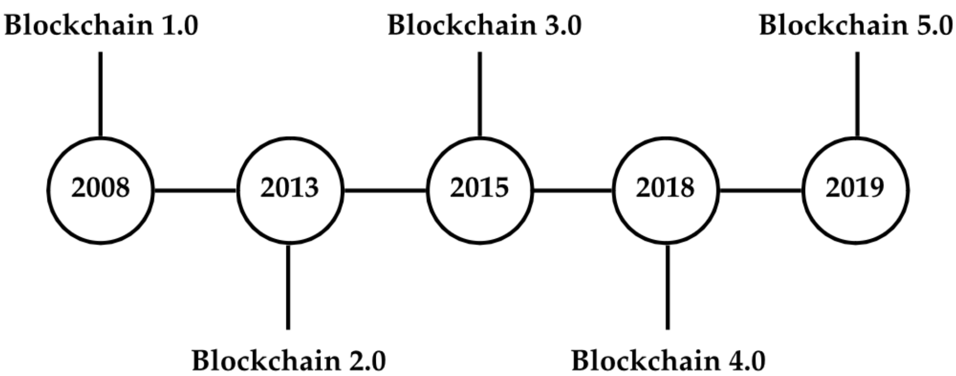


Figure 1.1: Timeline Intro

1.1.2. Blockchain Trends

It is particularly interesting to observe the exponential growth of blockchain technology from its inception to the present. Not only has it expanded significantly in terms of market size, but it has also experienced a rapid increase in user adoption in various sectors. This growth reflects both the rise in the monetary value of the blockchain industry and the broadening use of its technology.

According to Precedence Research (2024), the blockchain market reached an estimated value of 17.6 billion USD in 2023, with projections for it to grow to 26.91 USD billion by the end of 2024. This expansion is driven by a compound annual growth rate (CAGR) of 52.9 %, which is expected to continue until 2030. By that time, the market size is forecasted to soar to 1.879 trillion USD, as reported in the Figure 1.2. These numbers reflect the increasing adoption of blockchain technology across various sectors, such as finance, healthcare, and supply chain management, where it offers advantages like enhanced security, transparency, and operational efficiency.

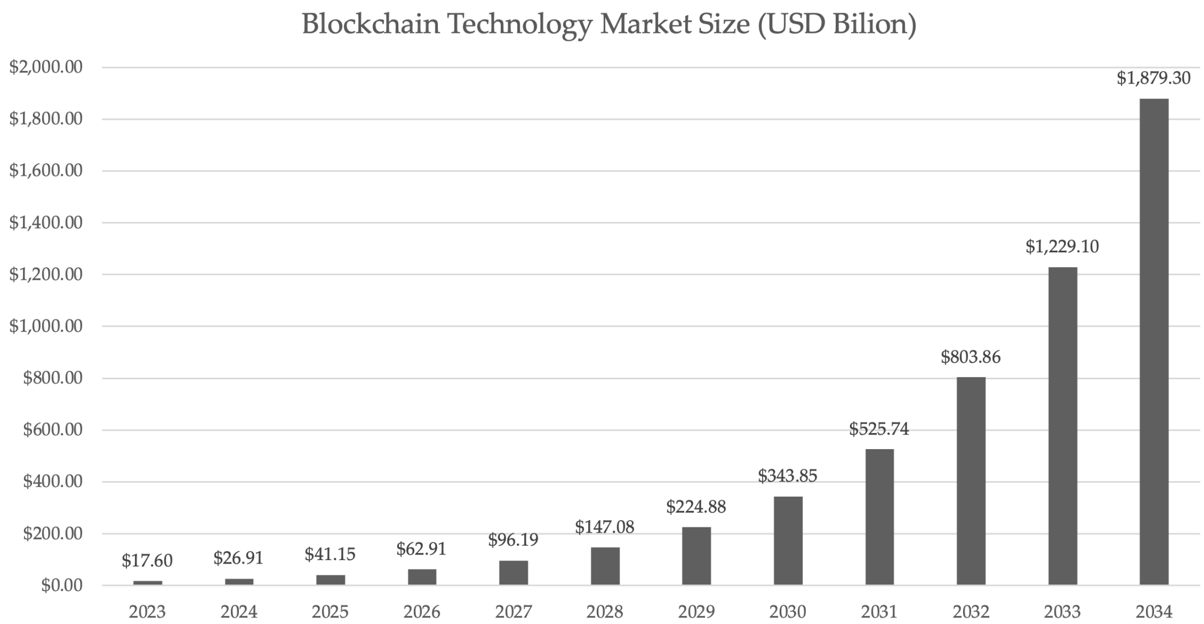


Figure 1.2: Blockchain Technology Market Size 2023 to 2034(USD Bilion) from Precedence Research (2024)

Shifting perspective to focus on the growth of blockchain use reveals some interesting parallels. As highlighted in the article by Young Platform (2024), the adoption of Blockchain follows a trend similar to that of the Internet in the 1990s, as demonstrated in the accompanying chart. However, while the Internet grew at an annual rate of 70 %, Blockchain has shown an annual growth rate of 137 %. The article emphasizes how the Internet went from having only a few users in 1990 to 5 billion today, covering 62.5 % of the global population over 33 years. If Blockchain were to follow a similar adoption curve, it could potentially reach 5 billion users around 2047.

Considering Blockchain's annual growth rate of 137 %, it's clear why cryptocurrencies have emerged as one of the best performing asset classes over the past decade. When looking at Bitcoin's statistics, the figures are truly remarkable. Despite several 80 % drawdowns, which are periods where the asset's price drops significantly from its peak, Bitcoin has increased by an astounding 13,000 % since 2014. Specifically, drawdowns are instances where an asset experiences sharp price declines, leading to heightened volatility. However, despite these fluctuations, the long term growth of both Bitcoin and Blockchain technology remains impressive.

In the article by Grand View Research (2023), an in-depth analysis of the sectors where Blockchain finds its most impactful applications was proposed, highlighting those industries that have benefited the most from the rise of this technology. Public cloud services played a dominant role in 2022, accounting for over 61 % of global revenues, meaning the total income generated worldwide by the Blockchain industry. Cloud providers offer highly scalable and cost-effective infrastructures, essential for supporting the growing Blockchain networks that require increasing resources to manage higher transaction volumes. Additionally, these providers invest heavily in security and compliance, which are critical for sectors such as finance and healthcare, where data protection is a top priority.

Based on the analysis of growth trends and the increasing attention blockchain technology has attracted, particularly within the financial sector, this thesis will focus on addressing key topics related to the blockchain world. The technology's transformative impact on finance through innovations like cryptocurrencies, decentralized finance (DeFi), and secure, transparent transaction systems shows its potential to reshape traditional financial systems. With its ability to enhance efficiency, reduce transaction costs, and improve transparency, blockchain represents a promising and highly relevant area of study. The decision to explore this topic further is driven by its ongoing evolution and significant potential for future financial innovation.

1.1.3. Blockchain structure and how it works

The Blockchain, initially created for Bitcoin, has expanded its influence to several industries including finance, healthcare, logistics, energy supply and more. The success of blockchain is mostly attributed to the elimanation of financial intermediaries. Indeed, the Blockchain enables users to engage in the exchange of digital assets as a means of monetary transaction, without the need for a central authority like banks.

There are other factors that contributed to the emergence of Blockchain technology. Indeed, as discussed in "A Taxonomy for Characterizing Blockchain Systems" by Alzhrani and Zhao (2022), Decentralised Finance, or DeFi, sought to address and enhance five fundamental aspects in contrast to conventional centralised finance:

1. **Control**: The proportion of deposits held by major banks in comparison to the total deposits held by other banks has experienced exponential growth in recent years, suggesting a significant rise in the dominance and impact of a small number of large banks over numerous smaller banks. For instance, in the United States, JP Morgan, Bank of America, Wells Fargo, and Citigroup had a significant increase in their share of deposits from 15% to 44% compared to other banks within a span of 40 years;

2. **Access**: Currently, there is still a significant portion of the population that lacks access to banking services. This demonstrates that even in the present day, banks remain inaccessible to a portion of the population. Indeed, a significant number of persons don't have access to financial services as they are considered high-risk by banks due to the absence of credit guarantees, hence impeding the assessment of their creditworthiness. In addition, banks generate much reduced fees from these individuals due to their relatively small deposits. Banks restrict individuals from their services because they believe that the dangers connected with offering banking services to these individuals are greater than the possible advantages. Currently, around 1.5 billion individuals lack access to a bank account;

3. **Inefficiency**: Conventional financial systems often display inefficiencies in several areas. For instance, the fees associated with transferring money between bank accounts can be quite high. Transferring funds to family members, for example, incurs a significant economic cost. Typically, remittance fees can range from 5 to 7 % of the transferred amount. Another drawback of traditional banking is the time it takes to complete a transfer. Funds are temporarily held up during the transfer process, rendering them inaccessible for a certain period. This delay can lead to liquidity issues, impacting individuals' ability to manage their daily financial activities effectively;

4. **Interoperability**: Traditional financial systems face significant challenges in terms of interoperability. The global banking landscape is characterized by a variety of technologies and standards, leading to inefficient operations and communication between banks. This lack of standardization can result in several inefficiencies, such as higher transaction fees and substantial delays, especially in international payments, which are further compounded by time zone differences. To address these challenges, conventional financial systems employ certain procedures to improve the

overall compatibility of transactional processes. One example is the SWIFT system, which standardizes financial communications across banks in multiple countries. While SWIFT enhances communication efficiency, it does not fully resolve all interoperability issues, particularly those related to newer and more advanced payment technologies;

5. **Transparency**: Conventional financial systems often suffer from a notable lack of transparency. Customers generally have limited visibility into a bank's liquidity and overall financial health. This lack of information is problematic, as it carries significant risks for consumers. In the event of a banking crisis, for example, individuals may face potential losses of their funds. Furthermore, clients frequently lack clarity regarding the regulatory framework governing international transactions. They may not be fully informed about the intermediary institutions involved, the duration of the transaction process, or the fees associated at each step. This could lead to uncertainties and potential financial drawbacks for consumers.

Therefore, the introduction of such technology has resulted in several benefits for users.

Blockchain has reduced transaction costs by eliminating brokers and financial intermediaries that imposed substantial commissions. The speed of transactions and the authorisation processes associated with them have also been enhanced by eliminating financial intermediaries. Moreover the availability of financial services, particularly for individuals who lack access to conventional banking services has been increased. Through the utilisation of a decentralised and unchangeable register, each transaction is documented with absolute clarity, hence minimising the likelihood of fraudulent activities and mistakes. The blockchain's security is improved through its decentralised operation. Indeed, there is no singular core of authority, but rather the structure is comprised of discrete nodes interconnected with one another. Transactions are conducted in a pseudonymous manner, allowing users to handle them autonomously without the need for intermediaries. This grants users a higher level of control over their data. To comprehend the means by which these advantages might be attained, it is imperative to closely examine the composition of the Blockchain and its primary components.

Specifically, following an analysis of the current academic research by the authors Alzhrani and Zhao (2022) on the operation of the Blockchain, attention can be directed towards the distinct characteristics of this technology:

- Peer-to-peer network
- Decentralised Ledger

- Consensus algorithms
- Platform
- Smart contract

Blockchain is typically categorized as a decentralized system designed to record transactions and distribute data. More specifically, it can be described as a Distributed Transactional Platform operating on a Peer-to-Peer Network. This network allows two computers to exchange data directly, without the need for a central server. The foundation of this system is built on mutual trust among users.

The distributed ledger is established by recording and verifying each transaction, which is then propagated by the nodes in the network, resulting in an extensive chain of nodes. A node is a device actively participating in the blockchain network, and there are various types of nodes, each fulfilling different roles. Transactions are collected and organized into blocks, and the blockchain itself is composed of a sequence of these blocks. Each transaction is recorded using cryptographic hash functions, which are crucial for verifying blocks and linking each block to its predecessor. Once a block is validated, the data is added to the blockchain and becomes immutable. This irreversible process, ensured by well-defined cryptographic protocols, guarantees a high level of security. Blockchain technology is particularly noted for its strong emphasis on security, especially in financial applications, where unauthorized access or fraudulent activity can have serious consequences.

The block size is a critical feature that varies depending on the specific blockchain and is influenced by various factors. Each blockchain is governed by its own protocol, which sets the maximum block size and thereby determines how many transactions a block can contain. Additionally, the choice of consensus mechanisms used by the blockchain, such as Proof of Work (PoW) or Proof of Stake (PoS), affects the maximum block size due to their distinct optimization requirements.

Larger blocks allow more transactions to be processed within a block, leading to cost savings. Conversely, smaller blocks facilitate faster transaction processing, resulting in shorter block propagation times compared to larger blocks. Occasionally, if there is consensus within the community, the maximum block size specified in a blockchain's protocol can be adjusted through either a hard fork (an incompatible change) or a soft fork (a compatible change).

Although block size does not significantly affect energy consumption, it remains an important factor, particularly in block validation processes. Larger blocks increase propagation times and marginally raise energy usage during block transmission. Conversely, having more transactions within a block reduces the total number of blocks needed to process a given volume of transactions, leading to decreased energy consumption per transaction. However, as previously mentioned, energy usage is a crucial consideration, especially concerning consensus methods.

In the blockchain industry, several consensus algorithms are used, but the most prominent are PoW and PoS, employed by Bitcoin and Ethereum, respectively.

The PoW algorithm involves verifying blocks by solving complex mathematical puzzles that require substantial processing power, resulting in high energy consumption. This process is known as "mining". Specifically, miners must find a unique code called "nonce" that, when combined with the block data, generates a hash code through specialized methods. After collecting a set of transactions and forming a potential block, miners compete to solve these mathematical problems to earn rewards, typically in the form of cryptocurrencies. Once a puzzle is solved, miners broadcast the block to the network, where other nodes verify its correctness before adding it to the Blockchain. The network automatically adjusts the difficulty of these puzzles to ensure consistent block propagation times. Anyone with the appropriate hardware can participate in mining, which aligns with Blockchain technology's goal of decentralization, avoiding a single governing authority overseeing transactions. The network's security is reinforced by the significant amount of energy required to attempt an attack. However, this energy consumption can be viewed as a drawback, along with the extended time required for block propagation and the high computational power needed for validation, which limits participation to users with substantial hardware resources.

In contrast, the PoS validation process autonomously selects the block validator node based on the amount of cryptocurrency staked and the duration of staking. Staking involves locking up cryptocurrencies within the Blockchain project, allowing users to partake in critical functions like block validation. These staked cryptocurrencies serve as collateral, ensuring network integrity and incentivizing the project's success. Validators receive rewards in the form of new cryptocurrencies, aligning their interests with those of the network and enhancing decentralization. Once selected, the validator node organizes approved transactions into a block and submits it to the network. Similar to PoW, other nodes control the block's validity, and if it is confirmed, the block is added to the network. As previously mentioned, validators are rewarded with transaction fees or cryptocurrencies. PoS results in significantly lower energy consumption and faster block propagation compared to PoW, improving transaction speed and scalability. However, PoS has weaker security and somewhat contradicts the decentralization objective of blockchain by narrowing the pool of eligible validators based on their staked amount.

Over time, blockchain technology has expanded its applications significantly. The term "Platform" refers to the foundational framework of a blockchain used to create specialized applications. These applications, known as dApps, utilize blockchain technology to manage security and privacy without relying on centralized servers. Currently, Ethereum is the leading blockchain for developing decentralized applications, with over 3,000 existing dApps.

"Smart contracts" regulate various operations enabled by blockchain technology, including the development of dApps, asset-digital exchanges, and money transfers. Smart contracts are computer protocols that automatically enforce the terms and conditions of a contract or transaction. They are designed to execute contracts only when specific conditions are met. This instantaneous and fully automated execution reduces the time and costs associated with contract management. The choice of programming language for smart contracts depends on the blockchain platform used. For instance, Ethereum primarily uses Solidity, with Vyper and Serpent also utilized, while Binance Smart Chain often employs Solidity and Polkadot.

1.1.4. Tokens and how the tokenization process works

Tokens are the fundamental digital entities that are created and exchanged on a blockchain network. When analyzing the historical progression of the blockchain, it becomes clear that Bitcoin, as the introductory cryptocurrency, serves as the initial manifestation of a digital token. The launch of Bitcoin, indeed, signaled the start of a new era in digital transactions, demonstrating the effectiveness of a decentralized currency without the participation of traditional financial institutions. Consequently, the functionalities of tokens have significantly expanded. Presently, a token has the capability to serve as a medium of transaction, symbolizing actual assets such as real estate or artwork, or symbolizing intangible entities like data or voting rights.

In the following paragraphs, namely in the taxonomy part, it will be provided a thorough classification of the tokens discovered in the Blockchain business by explaining their various capabilities and the intrinsic and external characteristics they have.

In order to achieve deeper comprehension of tokens, it is fundamental to initially construct a basic classification, prioritizing the distinction between Fungible Tokens (FTs) and Non-Fungible Tokens (NFTs).

FTs are characterized by their interchangeability, which means that all FT tokens within a project have identical value and qualities. This allows them to be traded with each other without any differentiation. Moreover, they possess the ability to be fragmented into smaller parts.

In contrast, the main characteristic of NFTs is their uniqueness: every token has its own specific attributes and hence carries an exclusive value. Consequently, NFTs are not interchangeable or divisible. NFTs are commonly created to represent the sole ownership of digital or physical assets.

Subsequently is essential to do an initial classification based on the functionality of the tokens:

- **Utility tokens**: provide consumers with the capability to access and use products or services within a blockchain ecosystem. Users often need to pay fees or use particular features offered by the platform. Utility tokens frequently offer rewards to users, commonly referred to as "rewarding tokens," in exchange for specified actions. This incentive and reward system is specifically designed to actively engage and drive consumers to participate in and stay inside the ecosystem.

- **Security Tokens**: are digitized representations of tangible investments in physical assets, such as ownership in a company, fractional ownership of real estate, or investment in funds. Consequently, they often provide opportunities to obtain income or property rights as well as to traditional financial processes. Security tokens must comply with regulations that are similar to those governing investments made through traditional business channels.

- **Payment tokens**: sometimes referred to as cryptocurrencies, function as a means of trade for obtaining goods or services. However, they frequently serve as tangible investments in a virtual currency. They can be compared to a fiat currency that exclusively circulates on the blockchain.

In any case, it is important to repeat that a more in-depth analysis on the classification of tokens will be conducted in the appropriate chapter of the taxonomy.

Every type of token leverages the inherent attributes of the blockchain, such as immutability, transparency and security, which are crucial for maintaining confidence and effectiveness in transactions. These characteristics ensure the safety, capacity to track and immutability of transactions, hence increasing users' trust in the system.

The development and management of blockchain tokens involve complex processes that require the use of smart contracts, particularly on platforms like Ethereum. These smart contracts automate the issuance, transfer and management of tokens according to predefined rules. Technical development encompasses various aspects of token design, such as usability, scalability and integration with existing systems, all crucial for ensuring the token's effectiveness and utility.

From an economic perspective, evaluating tokens is challenging due to their inherent volatility, lack of intrinsic value and the speculative nature of the markets in which they operate. As discussed in the paper "Review of Blockchain Tokens: Creation and Evaluation" by Marin et al. (2023), the assessment of these tokens was influenced by market supply and demand dynamics, regulatory frameworks and broader macroeconomic conditions. Determining the value of tokens involves sophisticated financial models and in-depth analysis to establish fair pricing and assess investment potential. A detailed valuation must consider technological, economic and regulatory aspects to ensure accuracy and reliability.

Tokens face several challenges, including regulatory uncertainty, limited scalability, interoperability issues and concerns about market acceptance and liquidity. To address these challenges, ongoing innovation in blockchain technologies is essential. Establishing clearer legal frameworks and developing robust economic models are also critical for supporting token ecosystems over the long term. Improving scalability and interoperability is crucial for overcoming the technological challenges associated with blockchain networks.

Tokens represent a significant advancement in the digital representation of value, offering versatile applications from simple transactions to complex digital agreements. As technology evolves, tokens are expected to have an increasingly deep impact, potentially transforming sectors such as finance, art and healthcare by providing more efficient, transparent and equitable methods for managing and exchanging value. This expansion will likely lead to greater adoption of blockchain technology fostering innovation and new business models across various industries.

Tokenization involves converting assets, which are typically indivisible, into divisible tokens on the blockchain. This process enhances the trading and management of these assets. Essentially, any object can be tokenized, including real estate, artwork and commodities.

The objectives of tokenization include increasing accessibility to investments and improving transaction efficiency. Asset tokenization breaks down an asset into smaller units, allowing a broader range of investors to participate. This is particularly beneficial for those who might otherwise be excluded due to high barriers to entry associated with traditional investments. Tokenization democratizes access to assets that are often considered illiquid, such as real estate or art, thereby reducing economic inequality and expanding investment opportunities.

The tokenization process begins with selecting the asset to be converted into digital tokens. These tokens represent ownership or shares in the underlying asset and can be bought and traded on blockchain-based platforms. Smart contracts automate and secure the management of ownership and rights associated with these tokens. They include the rules and conditions for token transactions, ensuring compliance with relevant regulations, such as Know Your Customer (KYC) and Anti-Money Laundering (AML) laws (Tan et al., 2023).

Tokenization addresses several challenges in traditional finance, such as lack of transparency, market inefficiencies and limited investment options. By leveraging blockchain technology, tokenization offers a fairer and more accessible framework for asset management and integrates compliance systems that discourage money laundering and illicit activities (Tan et al., 2023).

For example, as discussed in "Decentralized One-Stop Solution for Real Estate" by Pocha et al. (2023), tokenizing real estate involves representing property ownership using blockchain-based digital tokens. These tokens represent fractional ownership and can be bought and sold on the market, similar to shares in a publicly traded company (Pocha et al., 2023).

The tokenization process begins with evaluating the property and determining the number of tokens that will represent its total value. Once created on a blockchain network, these tokens are available for purchase by investors. Smart contracts manage transactions, ensuring secure and transparent documentation of each token transfer. Investors can buy tokens in any quantity, gaining proportional ownership in the property and related rights, such as rental income (Pocha et al., 2023).

Traditionally, real estate has been known for its limited liquidity. Tokenization enhances the buying and selling of property shares, improving liquidity and offering greater convenience for investors. By lowering the minimum investment amount, tokenization allows a wider range of investors to participate in real estate, even with limited capital. Moreover, every transaction is meticulously recorded on the blockchain, ensuring transparency and traceability, which reduces fraud risk and builds investor confidence (Pocha et al., 2023). Eliminating intermediaries like real estate brokers and banks streamlines the property transfer process, cutting costs and reducing transaction times.

1.1.5. The most widely used smart contracts

Undoubtedly, Ethereum stands out as the leading platform in the blockchain industry, largely due to its highly efficient smart contract capabilities. This platform has fundamentally reshaped how smart contracts are designed and executed, making them readily accessible and versatile for a wide range of applications.

As highlighted in the paper "Review of Blockchain Tokens: Creation and Valuation" by Marin et al. (2023), two prominent smart contract standards on Ethereum are ERC20 and ERC721. These protocols are essential for creating FTs and NFTs, respectively. Their introduction has streamlined the process of generating and managing digital tokens, facilitating their use across various economic and creative contexts. The adoption of these standards has improved consistency and compatibility among different Ethereum-based applications and platforms.

The ERC20 standard sets a framework for interchangeable tokens on the Ethereum blockchain. ERC20 tokens are fungible, meaning each token of the same type holds an equal value, which is ideal for creating cryptocurrencies or digital assets that require uniformity. This standard has greatly simplified token creation and management, enabling seamless integration and interoperability across various platforms and applications.

ERC20 smart contracts define essential functions for token transfers, allocation and permission management. They ensure secure transactions and accurate record-keeping of token balances across addresses on the network. This transparency and security have enhanced user trust and accelerated the adoption of blockchain technology. Additionally, ERC20 tokens integrate effortlessly within the broader Ethereum ecosystem, making them easily exchangeable on cryptocurrency exchanges, manageable via popular digital wallets and compatible with various dApps. This compatibility has fostered a dynamic and adaptable marketplace, increasing the utility and value of these tokens.

In contrast, the ERC721 standard is used to create non-fungible tokens, each of which is unique and can represent distinct assets. This makes ERC721 ideal for applications requiring the representation of unique attributes, such as digital art, collectibles or exclusive property claims. ERC721-based NFTs have revolutionized the digital asset landscape by allowing for secure and transparent management and trading of unique assets.

NFTs created with the ERC721 standard are distinguished by their unique properties, which are crucial in markets like digital art or virtual real estate, where an asset's value can be heavily influenced by its specific characteristics. ERC721 contracts use algorithms to track individual token ownership, ensuring that transactions and ownership transfers are accurately recorded on the blockchain. This high level of security and transparency significantly reduces the risk of fraud and duplication, supporting the integrity and reliability of the NFT market and fostering widespread adoption and innovation.

The adoption of ERC20 and ERC721 standards has led to the development of a broad range of economic and artistic applications. ERC20 has enabled the creation of custom digital currencies and reward systems for dApps, while ERC721 has driven the rapid growth of the NFT sector, impacting industries such as art, gaming and digital collectibles.

Moreover, these smart contracts have established a unified and compatible development environment on Ethereum, allowing developers to create more complex solutions and integrate services across multiple platforms (Marin et al., 2023). This cohesive development environment has accelerated the expansion of the Ethereum ecosystem, enabling more effective collaboration among developers and fostering the creation of advanced, interconnected applications.

1.1.6. Initial Coin Offering

After analyzing the fundamental components of Blockchain technology and tokens related to various project, this section will explore an important mechanism through which these tokens enter into the market: Initial Coin Offerings (ICOs). Understanding ICOs is crucial for gaining insight into the valuation landscape of crypto projects and their respective tokens. Indeed, to fully comprehend how these tokens interact with the market, it is essential to examine the methods through which they are introduced and traded, with ICOs being one of the most prominent.

Just like the conventional financial secondary market, indeed, also the blockchain ecosystem has developed its own version: ICOs. ICOs serve as a fundraising mechanism where enterprises raise capital by selling digital tokens to early investors, typically in exchange for established cryptocurrencies like Bitcoin or Ethereum. This method democratizes access to funding, allowing innovative projects to secure financial support without the constraints of traditional financing routes, which are often unavailable or overly regulated.

ICOs resemble an initial public offering (IPO) in that they offer a way for companies to raise funds from the public. However, instead of selling company shares, ICOs sell tokens, which may not confer ownership or voting rights. These tokens can vary widely, including utility tokens that provide access to a service or security tokens that may represent ownership in an asset or company.

Ethereum's widespread use has been pivotal in the proliferation of ICOs. Its ability to execute smart contracts has enabled the creation and management of new digital tokens, tailored to the specific needs of each project. This has significantly enhanced the attractiveness and functionality of ICOs.

According to the paper "Tarzan and Chain: Exploring the ICO Jungle and Evaluating Design Archetypes" by Bachmann et al. (2022), ICOs gained prominence during the 2017 Bitcoin boom. Companies turned to ICOs to bypass the complex and highly regulated traditional financing methods.

These conventional methods often present challenges, such as requiring significant collateral or navigating intricate regulatory frameworks, particularly for small businesses and startups. ICOs offered an alternative that allowed entrepreneurs to access a global pool of investors more easily.

Investors in ICOs generally make decisions based on detailed evaluations of the tokens offered. They invest in tokens they believe have high growth potential and aim to profit by selling these tokens at a higher price. The rapid growth and popularity of ICOs have attracted many speculative investors, which increases the risk associated with these investments.

ICOs have significantly impacted the development and acceptance of blockchain technology by providing a new avenue for startups to secure necessary funding. However, the lack of regulation and the ease with which ICOs can be launched, have led to numerous cases of fraud and failed ventures, highlighting the need for greater oversight and standardization in this area (Bachmann et al., 2022), (Toepffer & Thatmann, 2020a).

The ICO environment illustrates how innovative financial methods can offer substantial opportunities while also introducing new risks. Striking a balance between fostering innovation and protecting investor interests is crucial. To mitigate these risks and create a more reliable investment ecosystem, stricter due diligence and transparent governance are essential.

Research in the study "Taxonomy and Universal Success Parameters of Token Models in Distributed Ledger Systems" by Toepffer and Thatmann (2020a) indicated a high historical failure rate for ICOs, with 92 % failing to meet their objectives. Despite this, there is growing academic and industry interest in blockchain and ICOs, reflecting recognition of their potential for significant impact despite the challenges (Toepffer & Thatmann, 2020a).

1.2. Blockchain Layer

1.2.1. Layer 0 and Layer 1

Blockchain topologies can exist in different structures, with multiple "Layers" that define their specific features and functionality (Gateway, 2024). These layers are built on top of each other, creating an intricate yet organized ecology. These "layers" can be conceptualized as a pyramid. The "Layer 0" Blockchain structures are located at the foundation of the pyramid. These structures primarily focus on carrying out three functions:

- **Security**: protocols must provide sufficient robustness to authenticate the accurate execution of transactions and invulnerability against cyber attacks;
- **Framework**: a software framework that enables the creation of Blockchain, Dapp, and other supplementary elements.
- **Interoperability**: refers to the ability of blockchains constructed on layer 0 to effectively communicate and interact with one another.

Undoubtedly, "Cosmos" is the most well-known example of Layer 0 projects. Indeed, the emergence of significant Blockchains like "Cronos Chain" can be attributed to the utilization of the "Cosmos SDK" framework. Cosmos stands out for its capacity to establish an interlinked ecosystem of blockchains, enabling seamless communication and transactions across many networks.

To summarize, Layer 0 projects serve as the fundamental building blocks of the Blockchain. Therefore, if they are not utilized for development purposes, their value is essentially negligible. Furthermore, Layer 0 is regarded as "non-compulsory." It provides increased adaptability and originality by enabling developers to construct personalized blockchains. It introduces an extra layer of infrastructure that promotes the establishment of a more interconnected and versatile blockchain ecosystem. However, a blockchain can still function independently without Layer 0.

Layer 1 blockchains are the foundational networks that serve as the underlying infrastructure of the blockchain. These networks are vital for the functioning of the blockchain ecosystem, since they provide the fundamental structure and functionality required for blockchain activities. Although layer 0 is not required, layer 1 is essential. These networks are responsible for performing the essential activities required for the existence of a Blockchain infrastructure.

- **Execution**: each transaction must be accurately processed;
- **Consensus**: refers to the algorithms that determine the validation of blocks. As discussed in earlier chapters, consensus mechanisms can vary in forms, with the

most widely used ones being PoW and PoS.

Ethereum and Bitcoin are widely recognized as prominent examples of Layer 1 blockchains. Blockchains serve as the fundamental infrastructure for many applications and systems, while also offering a crucial level of security and dependability necessary for the operation of a decentralized ecosystem. Most of these networks primarily focus on guaranteeing security and effectively administering smart contracts, in addition to the essential functionalities mentioned above. This enables the development of additional features like dApps within the ecosystem.

Layer 1 blockchains have inherent limitations, specifically in terms of scalability. They are unable to efficiently process a large volume of transactions and incur high fees. The primary motivation behind the development of Layer 2 solutions is to address these limits by enhancing transactional capacity and reducing costs, while maintaining the security and integrity of core networks.

1.2.2. L2

Layer 2 solutions (L2) are protocols built on top of Layer 1 blockchains. While Layer 1 Blockchains provide the core infrastructure, ensuring security and decentralization, they often face limitations in handling a large number of transactions efficiently. These projects have had substantial growth in deployment in recent years and are currently a prominent topic in the Blockchain community. Layer 2 solutions have become crucial for enhancing blockchain efficiency and scalability by solving issues that cannot be resolved just by Layer 1 networks. In particular, classical Layer 1 networks such as Ethereum (ETH) and Bitcoin (BTC) face significant scalability limitations. These networks are only capable of processing a limited number of transactions per second, and the associated transaction fees tend to be quite high, especially during periods of network congestion. This is where Layer 2 solutions come into play, indeed are designed to enhance the overall scalability of the network. Layer 2 solutions aim to offload a portion of the transaction processing from the main blockchain, thereby reducing congestion, improving transaction speed and lowering fees. These solutions remain closely tied to Layer 1, as they rely on its security and consensus mechanisms to finalize and validate transactions, ensuring that any enhancements in scalability do not compromise the integrity or security of the network. In this way, Layer 2 solutions complement the fundamental structure of Layer 1 blockchains, offering a more efficient and scalable system while preserving the trust and security of the base layer.

1.3. DEX

As discussed above, blockchain technology has introduced numerous innovations in various sectors. Among these, the financial sector emerges as one of the most affected, as blockchain was developed with the aim of improving the traditional financial system. One of the most promising and functional applications of blockchain is decentralised finance. In particular, increasing attention is being created around decentralised exchange platforms.

DEXs are defined as decentralised environments in which users interact with each other directly, namely without the presence of intermediaries such as banks, to exchange financial products. Such environments are built using blockchain technology and therefore take advantage of the latter's security protocols. Indeed, every transaction that takes place within the DEX environment is recorded on the Blockchain and is therefore visible to all participants, and moreover, once recorded, is immutable.

Being built and rooted on a Blockchain network, these decentralised exchange environments can be categorised as true decentralised applications. Unlike centralised structures, such as CEXs, in a decentralised exchange each user has direct control over his or her asset via a private key, which is not given to the service provider. This directly aligns with the core principle of blockchain technology: decentralization. In particular, this structure further boosts the security of the platform, as users are less exposed to risks such as manipulation associated with centralized control. Additionally, the open source nature of many DEX protocols fosters transparency and trust within the community.

DEXs are also critical for promoting financial inclusion, enabling anyone with internet access to participate in trading without facing the typical barriers imposed by centralized systems. As blockchain technology continues to grow, DEXs have seen a rapid increase in both user adoption and transaction volumes, making them a key driver of innovation in the DeFi ecosystem, where autonomy and decentralization are fundamental.

1.4. Research Objectives

Of all the topics discussed thus far, specifically regarding blockchain, this thesis will focus on two fundamental aspects: token taxonomy and valuation.

These two themes have been selected as separate objectives due to their high relevance and significance in the evolving field of blockchain and cryptocurrencies. The taxonomy of tokens will be explored first, as it plays a particularly pivotal role, influencing the overall approach to valuation by providing a structured classification system that supports the analysis of token characteristics. By addressing taxonomy first, this thesis aims to establish a foundation that directly informs and impacts the methodology used for token valuation. Taxonomy and Valuation are crucial not only for academic research but also for practical applications within the blockchain ecosystem. By first establishing a clear and robust taxonomy, this research will contribute to creating a structured framework that helps in understanding and categorizing the diverse range of tokens currently in circulation. A well defined taxonomy is necessary for regulatory purposes and for facilitating interoperability among different blockchain platforms and it serves as a critical precursor to effective valuation. The approach to valuation, in turn, depends heavily on the taxonomy, as it allows for a more precise evaluation of a token's utility, functionality and potential for growth. Consequently, by addressing taxonomy before valuation, this thesis ensures a logical progression in tackling these two interconnected but distinct issues, ultimately leading to a more comprehensive understanding of token dynamics in the blockchain landscape.

1.4.1. Taxonomy

The cryptocurrency landscape is marked by significant volatility and rapid change. Since its inception, innovative projects and implementations have continually transformed token features, leading to a dynamic and evolving ecosystem with an exponential increase in token functionality and characteristics.

How reported by Alzhrani and Zhao (2022), the substantial degree of customization in each token and project complicated the development of a unified taxonomy. Despite various attempts to classify tokens into specific categories, establishing a consistent taxonomy remained a challenging goal (Puschmann & Huang-Sui, 2024).

How Toepffer and Thatmann (2020a) discussed in their study, a well defined taxonomy of tokens is crucial for addressing regulatory questions, fostering innovation and improving understanding and interoperability. By breaking down tokens into their fundamental components, they can be repurposed and innovated more effectively within the blockchain ecosystem. This approach also colud help to create a token classification hierarchy that is clearer and more intuitive. Given the ongoing advancements in blockchain technologies and the growing complexity of cryptocurrency projects, existing taxonomies must be updated.

The primary objective of this thesis has been to review the existing literature in the current landscape to understand the fundamental characteristics of token taxonomies. This involved analyzing the points of convergence and divergence between the proposed classifications and identifying the key attributes that a comprehensive taxonomy should include. This analysis aims to address the problem of a unified taxonomy, with the additional goal of identifying the most significant dimensions and variables on which to focus the valuation at a later stage. The methodology employed for this review was a systematic literature analysis.

RQ : *"What are the key features at both the system and token levels that enable a more effective and comprehensive classification of Distributed Ledger Technology (DLT) systems and associated tokens?"*

1.4.2. Valuation

The assessment of cryptocurrencies and DeFi tokens is a growing subject with considerable academic and scientific importance. The interest in this subject is driven, in part, by the swift development and widespread adoption of blockchain technology and decentralised platforms, which are fundamentally reshaping the worldwide financial environment.

The decision to focus on token valuation in this thesis stems from the substantial gaps and complexities still present in the current literature (Metelski & Sobieraj, 2022). Despite the rising significance of cryptocurrencies and DeFi tokens in global financial markets, their valuation remains largely underexplored.

Kaal et al. (2022) discussed that traditional financial models, designed for conventional assets, often fail to accommodate the decentralized, rapidly evolving nature of digital assets. Tokens, unlike typical financial instruments, lack intrinsic value tied to tangible assets or predictable revenue streams, making standard valuation methods inadequate (Liu & Zhang, 2023).

Additionally, as studies made by Marin et al. (2023) and by Şoiman et al. (2023) reported that the speculative nature and volatility of cryptocurrency markets further complicate valuation. These assets are heavily influenced by market sentiment, collective behavior, and external factors such as regulatory changes and macroeconomic conditions, which are not easily captured by conventional financial frameworks. This volatility, in contrast to traditional assets, adds to the unpredictability and necessitates a more adaptable approach.

These issues highlight the necessity of conducting a comprehensive examination of the existing body of literature in order to investigate and assess the present condition of token creation and valuation. Conducting a comprehensive literature review can assist in identifying deficiencies in existing knowledge. Additionally, analyzing grey literature and forum discussions can offer practical, up-to-date insights that enhance academic research, leading to a more comprehensive and nuanced understanding of the cryptocurrency and DeFi token markets.

The gap in the literature becomes particularly significant when dealing with tokens that do not generate revenue streams. While in tokens generating revenue streams, classical valuation models such as discounted cash flow (DCF) can be adapted, although this remains challenging due to the high volatility of these assets. For tokens without cash flows, the crucial link between their value and the underlying project lies in how effectively the token captures the value generated by the project. In other words, the valuation should focus on the extent to which the success and impact of the project are reflected in the token itself.

RQ: *"What are the key characteristics to be considered when performing a token valuation?*

The primary objective of this thesis is to propose and structure a methodology to perform a token valuation. The literature review has provided several points of reflection, although a clear methodology or framework has not emerged. For this reason, it was decide to choose a relative valuation method, taking into account parameters that still reflect the findings from the valuation review. The starting hypothesis is that certain core parameters are universally relevant across all blockchain based projects, while others are critical and specific to certain types of projects. The next phase involved selecting two classes of blockchain projects, specifically Layer 2 solutions and decentralized exchanges. The motivation for choosing L2 and DEX projects lies in their distinct roles within the blockchain ecosystem and their influence on scalability and decentralized finance, respectively. These projects offer a diverse yet relevant context for testing the proposed valuation methodology. These literature reviews of L2 and DEX are presented in Chapters 5 and 6, respectively, providing an in-depth analysis of the key characteristics, challenges and areas of interest that informed the identification of fundamental parameters for valuation. The literature review allowed to pinpoint critical features that distinguish these projects, as well as the core issues that need to be addressed for accurate valuation. Subsequently, Chapter 7 presents the empirical tests on L2.

2 | Methodology

Before undertaking the literature review, a comprehensive strategy was formulated to determine the most suitable methodological approach. A search in the scientific article database provided diverse insights that were integrated into the papers, guiding the research and writing process.

In alignment with the recommendations by Barry et al. (2022), it is crucial to conduct a methodological review that defines the current State of the Art (SoA) to pinpoint gaps in existing knowledge. The analytical approach used in this paper is particularly noteworthy as it advocated for a strategy that was critical during the initial research stages. Specifically, it is advised to develop a foundational understanding of the subject area and gain experience with scientific literature through a detailed review of relevant publications. This strategy, which has been applied throughout the early phases, allowed for the establishment of a solid base of initial knowledge and fostered a critical perspective on the topics under investigation. Consequently, this approach facilitated an understanding of the various viewpoints, claims and critiques present in the literature.

It is essential to recognize that the initial knowledge acquired during this phase is provisional and subject to change, as it arises from a preliminary, non-systematic research phase. Nevertheless, this initial groundwork has paved the way for a more deliberate and structured approach in the subsequent literature review.

Additionally, Torres-Carrion et al. (2018) have introduced the concept of the "current state of the problem" evolution to support this methodology. They have distinguished between the initial phase of research, referred to as the "MY" Current State of the Problem Research, and the systematic research process, which should evolve into the "THE" Current State of the Problem Research. This distinction has emphasized the progression from preliminary, less structured exploration to a more rigorous and tangible research framework.

The paper by Mohammed et al. (2021) was also a determining factor in the selection of the revision methodology to be followed. In particular, this provided a detailed description of the various methodologies that can be employed to conduct a literature review:

- Systematic;
- Semi-Systematic;
- Integrative.

The paper argued that the systematic approach is the most efficient approach in dealing with technical and managerial materials. The systematic approach was initially adopted to conduct the scientific paper research. However, after analyzing various types of literature reviews, it became evident that a deep analysis required the integration of elements of both semisystematic and integrative methodology. This approach ensured a more comprehensive examination of the subject matter. Indeed, it is explicitly stated in the paper's guidelines by Mohammed et al. (2021) that during the literature review design phase, it is essential to align the method to the research topic on a regular basis.

2.1. Literature Review Methodology

The PRISMA method, which has been extensively employed by Moher et al. (2009), Mengist et al. (2019), Torres-Carrion et al. (2018) and has been updated by Page et al. (2021), was selected for the purpose of conducting the schematic revision of the literature. As discussed by Moher et al. (2009):

The PRISMA Statement consists of a 27-item checklist and a four-phase flow diagram. The aim of the PRISMA Statement is to help authors improve the reporting of systematic reviews and meta-analyses.

In the following sections, the steps that led to the selection of papers identified for the literature review will be detailed. Each paragraph will explain the rationale behind the choices made, including the criteria for inclusion and exclusion. The selected papers were chosen based on their relevance, contribution to the topic and the credibility of their methodologies. The literature review aimed to cover a broad range of perspectives, ensuring a comprehensive understanding of the subject.

2.1.1. Taxonomy Literature Review

The methodology employed for this review was a systematic literature analysis, and, following the approach outlined by Toepffer and Thatmann (2020a), the subject of taxonomy was examined from three distinct perspectives: regulatory authorities, industry practitioners, and academics. This methodology has proven to be particularly comprehensive and effective, as it allows for a multifaceted examination of the issue, taking into account the most significant parameters and covering every detail. An in depth analysis of the scientific literature provides a well structured and detailed view of the current state of research, identifying the latest trends and innovations in the field of crypto tokens. However, given the dynamic and rapidly evolving nature of cryptocurrencies, it was necessary to complement this analysis with a review of grey literature, including reports, articles and analyses from cryptocurrency investors and market analysts. This pragmatic approach offers a more current and applicable view of real world practices and user perceptions. Furthermore, examining the criticisms and regulations imposed by institutional bodies is essential for understanding the normative context in which tokens operate. This involves evaluating existing regulations, proposed guidelines and compliance measures established by regulatory authorities. The integration of these three perspectives provides a comprehensive understanding of the factors influencing the classification and success of tokens, facilitating the creation of a robust taxonomy that can be applied in various scenarios to enhance interoperability and standardization within the blockchain ecosystem.

The literature search was conducted using the following search query in the Scopus database.

(token OR crypto OR crypto-asset OR dlt) AND blockchain AND taxonomy

The research conducted on Scopus using this query reflects a strategy to explore a wide range of concepts related to blockchain, cryptocurrencies and DLT. The inclusion of DLT within parentheses was a deliberate choice, as many taxonomies address these topics at a macro level, referring not only to blockchain but also to DLT systems more broadly.

The goal of the chapter is to map the taxonomies of the blockchain world by adopting a dual perspective: on the one hand, considering DLT systems from a global view, and on the other, delving into the specific characteristics of tokens and cryptocurrencies. Adding the term DLT to the search not only broadens the literature coverage but also enriches the analysis of taxonomies by including technologies that extend beyond traditional blockchain, encompassing other forms of distributed ledgers. This approach provides a more comprehensive view of the dynamics governing these emerging technologies.

The PRISMA method, shown in figure 2.1, was employed to effectively identify the essential articles for conducting the literature review that were extracted from the emerging papers.

As of September 4, 2024, a total of 70 papers have been collected. Reading the title and the abstract, 44 papers that are not directly related to the concept of taxonomy or related concepts have been excluded. Indeed, many of the papers identified are applica-

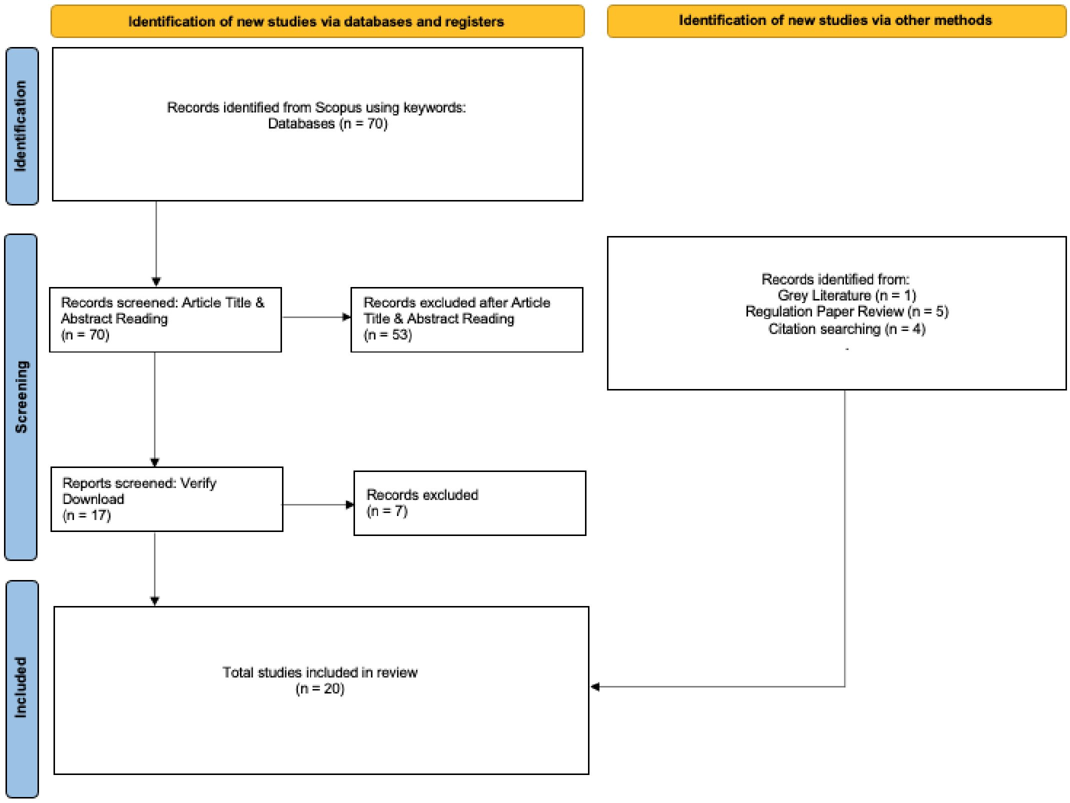


Figure 2.1: Taxonomy Prisma

tions within specific fields that stem from existing classifications. The application fields are numerous and range from computer science to the energy sector, which is indicative of the fact that token technology has numerous applications. Additionally, several articles that used taxonomy as a starting point to present their own proposals in the crypto space, including the introduction of new token types, were also excluded. After reading them, 9 papers were found that, despite the clear references to the taxonomy in the title and in the abstract, were not correlated with the objective of obtaining a classification proposal. The remaining papers, which were thoroughly examined, have developed proposals, which is why they were incorporated into the literature review. Furthermore, 7 results are unavailable for download. 6 of the 10 remaining papers meet the necessary criteria to compare the proposed taxonomies, while the remaining papers are useful for further exploration. These criteria involve the presence of a taxonomy focused on the classification of tokens in a specific way or at a macro level within token systems. The selection criteria and results are elaborated in the designated chapter.

Ultimately, 5 papers were later added in order to broaden the research in specific sectors. One of these items was selected from the grey literature as a significant highlight following a comprehensive review of the available material. The concept of incorporating grey material is introduced by Toepffer and Thatmann (2020a), which emphasised the importance of approaching taxonomy from a triple perspective: academic, grey material and the bureaucratic side of the current regulations.

Moreover, an investigation was conducted to revise the regulations, which resulted in the inclusion of 5 papers. The previously mentioned elements were employed to create the "Regulation" paragraph.

2.1.2. Valuation Literature Review

The methodology included the use of both scientific papers and grey literature. The latter encompasses a wide range of online content such as blogs, articles, white papers and discussions in cryptocurrency forums. These sources often offer rapid, practical analysis and insights, complementing the more formal approach of traditional academic research.

The literature search was conducted using the following search query in the Scopus database.

blockchain AND valuation AND (asset OR token* OR crypto)*

The research conducted on Scopus using this query demonstrates a targeted strategy aimed at exploring the intersection of blockchain technology and the valuation of various digital assets, including tokens and cryptocurrencies. The use of a wildcard (*) after “asset” and “token” allows for the inclusion of multiple variations of these terms, capturing a broader range of studies that might refer to different types of assets or tokens.

The goal of this query is to analyze how valuation methodologies are applied within the blockchain ecosystem, specifically in relation to assets like tokens. Including a various set of terms ensures that the search covers a wide array of literature on how these digital assets are valued, whether through financial, technical or market-based approaches. The search query effectively broadens the scope of the research, facilitating a comprehensive review of the ways in which blockchain-based assets are valued in different contexts.

The PRISMA method, shown in figure 2.2, was employed to effectively identify the essential articles utilized for conducting the literature review, which were extracted from the emerging papers.

By September 4, 2024, the research had produced 79 papers, of which 57 were exluded based on their titles and abstracts. Indeed, papers that do not directly address the concept of valuation in a comprehensive manner were excluded. Various articles concentrate on the researcher’s perspective rather than compiling methodologies and reflection points

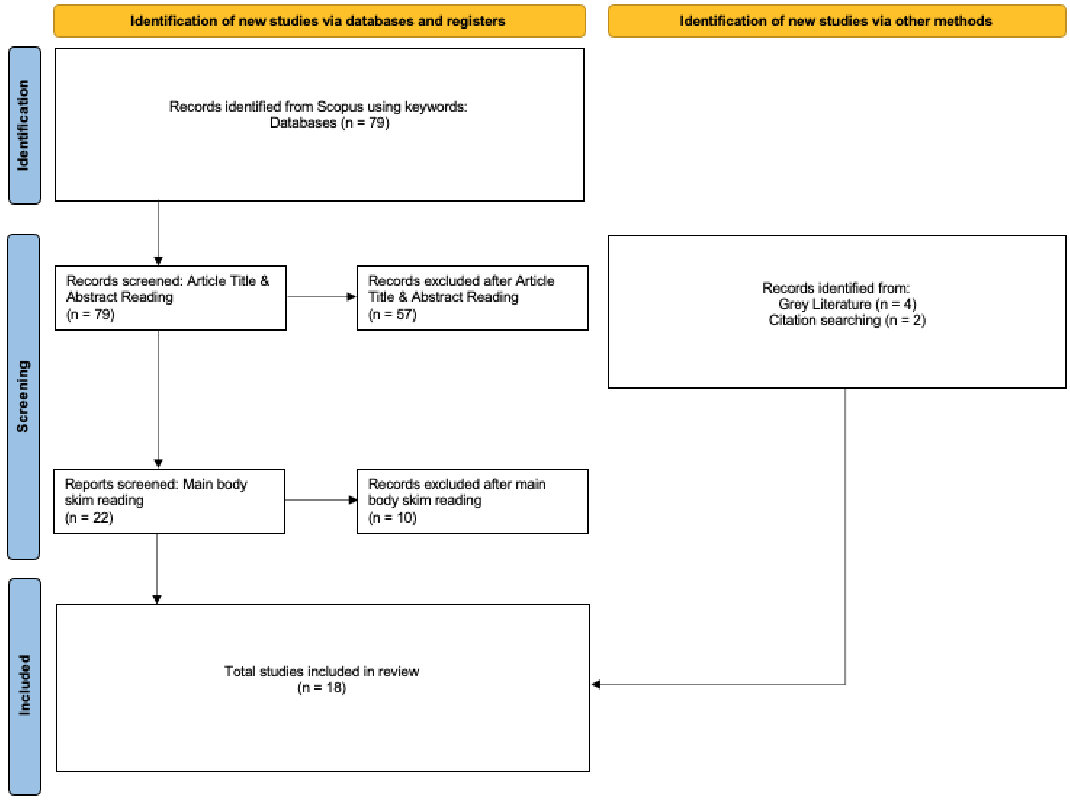


Figure 2.2: Valuation Prisma

relevant to evaluation techniques in the realm of cryptovalue. Other papers were excluded because they deviated from the research objectives. In this chapter, 10 papers weren't considered to be useful after being analysed, despite the fact that both the abstract and the title was aligned with the objective. The metrics proposed by these latter authors are either inadequate or insufficient. Therefore, 14 academic papers were employed to compose the chapter on the revision of valuation literature. The results of the papers have enabled the compilation of the methodologies that are currently in use in the scientific literature for the evaluation of cryptocurrencies and tokens. Among the academic papers used, 2 were subsequently incorporated to facilitate further exploration. Additionaly, the chapter was supplemented by 4 articles from the grey literature that were particularly relevant. Indeed, in the context of evaluation, it is extremely interesting to examine the methodologies proposed by analysts and practitioners.

2.1.3. L2 Literature Review

The literature search was conducted using the following search query in the Scopus database.

Blockchain AND Layer 2 AND scalability AND solutions

The research on Scopus with this query shows that Layer 2 solutions are emerging as promising answers to the scalability problems of major blockchains such as Bitcoin and Ethereum. The goal is to identify and analyze how Layer 2 technologies address the scalability challenges that limit mainline blockchains. These solutions, such as payment channels and sidechains, are designed to increase the number of manageable transactions without compromising security or network decentralization. The analysis of the publications obtained from this query helps to understand the advances, innovations and challenges associated with the implementation of these technologies, providing insights into current and future trends in this area.

The PRISMA method, illustrated in Figure 2.3, was utilized to systematically identify the key articles necessary for the literature review, which were extracted from the emerging papers.

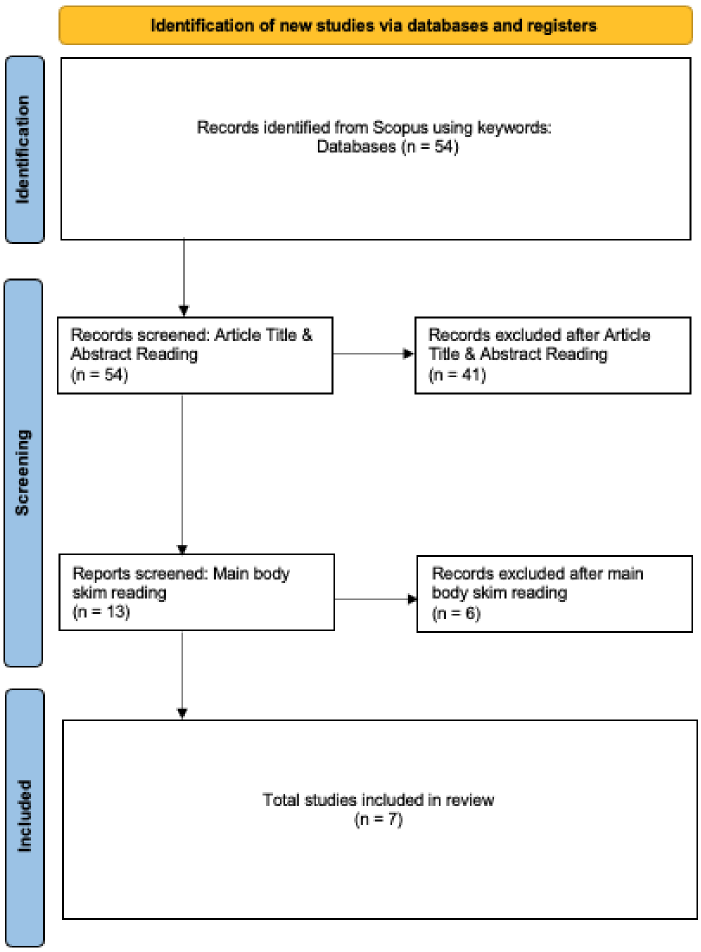


Figure 2.3: L2 Prisma

54 papers were found from 2018 to September 4, 2024. After a review of the title and tha abstract, 41 were discarded . Those papers that contained the keywords sought but focused their searches on specific applications not inherent to our purpose were discarded. Indeed, some of these papers discuss the applicability of the Layer 2 systems to areas such as electronic voting, e-commerce and machine learning techniques. In particular, the papers initially appeared relevant to our study, but a deeper analysis revealed that their focus was more on the practical applications of Layer 2 solutions rather than exploring their fundamental mechanisms or the various proposed solutions in detail.

Additionaly, 6 more papers were discarded after a detailed review. These papers, while seemingly aligned with our research goals based on their titles and abstracts, turned out to be overly technical. They provided in-depth analyses of specific Layer 2 solutions, lacking the broader overview needed for our examination of Layer 2 systems in the blockchain ecosystem.

7 papers were finally used. These papers were reviewed and used to analyze the main Layer 2 solutions currently available in the blockchain ecosystem. These papers facilitated the creation of a comprehensive overview of Layer 2 systems and their fundamental workings. In addition, they were essential for a thorough understanding of the issues of Layer 1 solutions, which are the starting point of the chapter.

2.1.4. DEX Literature Review

The paper search was conducted using the following search query in the Scopus database.

blockchain AND dex

The research conducted on Scopus using this query reflects a focused approach aimed at exploring the relationship between blockchain technology and DEX. The simplicity of the query is intentional, as DEXs are a relatively recent topic in academic literature. As a result, even with such a straightforward query, the amount of relevant information retrieved is limited.

The goal of this query is to investigate how decentralized exchanges, built on blockchain technology, are being discussed and analyzed in the current body of research. Despite the growing popularity of DEXs in the industry, their relatively new presence means that comprehensive academic studies on the subject are still developing. This makes a concise query like blockchain AND dex sufficient to capture the available literature, while also highlighting the need for further exploration and expansion of research in this emerging area.

The PRISMA method, shown in figure 2.4, was utilized to systematically identify the key articles necessary for the literature review, which were extracted from the emerging papers.

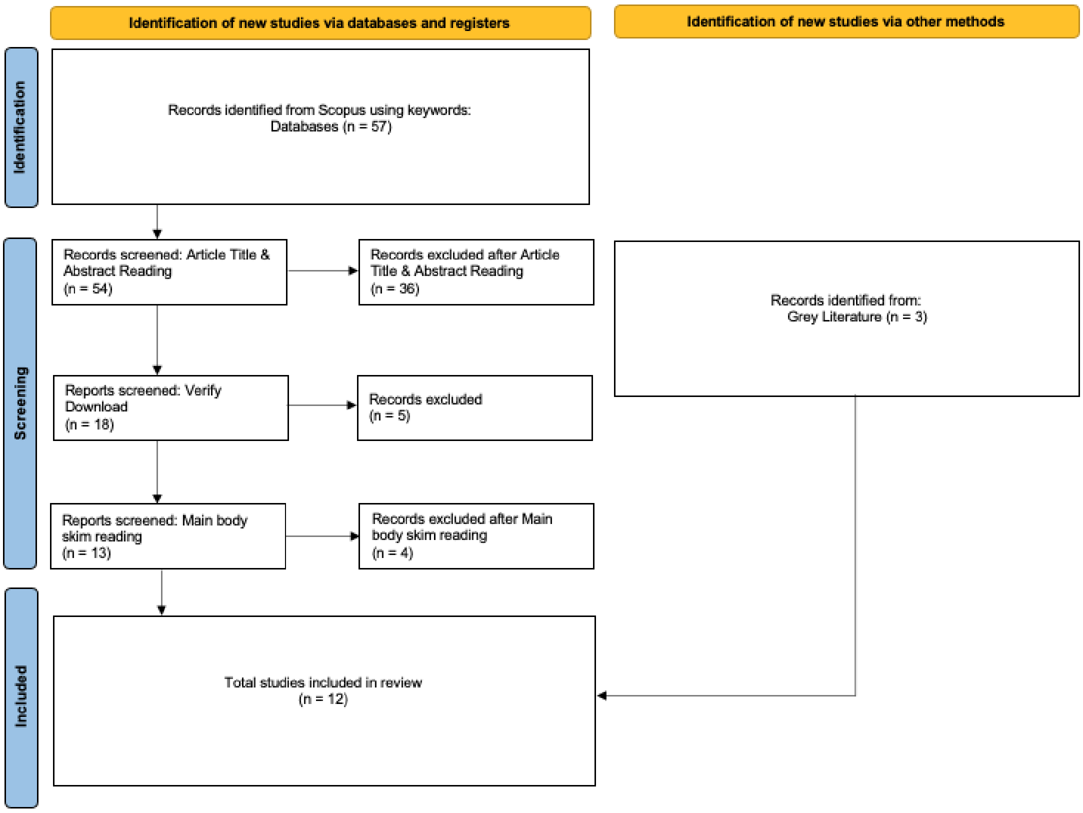


Figure 2.4: DEX Prisma

After conducting the research, 57 papers were identified from 2018 to 4 September 2024 .

29 papers were eliminated following a title and abstract revision. Many of these latter ones were employed by the authors to promote their projects in the DEX domain. While these articles are interesting, they do not represent the type of material that is typically sought when attempting to define a clear picture of scientific literature in the DEX field. Papers were selected where the titles provided a broader reference to the DEX landscape. These papers were then analyzed to understand their characteristics and the relevance to our study. Other papers were found to be unrelated to the desired characteristics. Moreover, other 4 papers were considered unsuitable after being read and analysed. Despite the fact that the assumptions were compelling, the areas of application were occasionally excessively confined to the applied mathematics.

5 of the remaining papers are unavailable for download. The remaining 9 papers were subsequently utilised and analysed. These latter ones have enabled the creation of an

exhaustive map of DEX applications from a variety of distinct perspectives. It was also particularly beneficial to analyse the websites and white papers of the primary token projects in the DEX sector in order to gain a practical understanding of their functionality. Ultimately, 3 papers were subsequently incorporated in order to broaden the research in specific sectors.

2.2. Empirical analysis Methodology

The methodology for the empirical tests is based on the findings from the literature reviews presented in the following chapters. Significant parameters for Layer 2 and decentralized exchanges were selected using the material gathered in the reviews. The decision was made to empirically test these parameters for L2 tokens, with the aim of identifying the most statistically significant factors.

Given the nature of the data, which consisted of time series, the SARIMAX model was deemed appropriate (Tiwari et al., 2023). This model is particularly well-suited for time series analysis as it can account for seasonality, trends, and the influence of exogenous factors, providing a more accurate and comprehensive forecasting framework. Before applying SARIMAX, a Variance Inflation Factor (VIF) analysis was carried out to verify whether multicollinearity existed among the selected variables. Once this was confirmed, the model was applied with adjustments for non-stationary variables, which were differentiated after being tested using the Augmented Dickey-Fuller (ADF) test.

During the analysis, it became clear that the residuals were not normally distributed. To address this, the logarithm of the variables was taken, a technique often used to stabilize variance and achieve a more normal distribution of residuals. Furthermore, since volatility persisted in the residuals, a Generalized Autoregressive Conditional Heteroskedasticity (GARCH) model was applied to account for time varying volatility. Instead of following the standard approach of assuming a normal distribution for the residuals, the GARCH model was fitted using Student's t-distribution. This choice is particularly advantageous because Student's t-distribution allows for heavier tails, making it more robust in capturing extreme variations in the data, which are common in volatile financial environments.

This combination of SARIMAX, logarithmic transformations, and GARCH modeling with Student's t-distribution provided a comprehensive approach to understanding the dynamics of the variables, ensuring more reliable and interpretable results, especially in a complex financial context such as Layer 2 blockchain systems.

3 | Taxonomy

This chapter is structured to provide a comprehensive overview of the taxonomy related to Distributed Ledger Technology systems and tokens. The first section focuses on a literature review of DLT systems and tokens, developing two different levels of analysis: a macro-level exploration of DLT systems and a more focused review of the specific characteristics of tokens. This dual approach helps to contextualize the broader technological framework while targeting the properties that define tokens within these systems.

In the second part of the chapter, the focus shifts to a key attribute of tokens: token types. Given the significance of this attribute in shaping the functionality and classification of tokens, an entire section is devoted to reviewing token types as discussed in academic literature and gray sources. This section serves to highlight the existing knowledge, trends and perspectives on token types across different sources.

Finally, a dedicated segment examines the regulatory and accounting implications surrounding token types. This is a particularly important area as the classification of tokens has substantial consequences for how they are registered and accounted for, making regulation a hot topic in this field. Understanding the relationship between token types and their regulatory frameworks is critical in shaping how these digital assets are treated in financial and legal contexts.

The objective of this chapter is to map out the existing scientific evidence and perspectives on taxonomy within the DLT and token ecosystems. By identifying key themes, points of convergence and areas of divergence, the chapter seeks to lay the foundation for a more detailed discussion in a future chapter focused on token valuation.

3.1. Paper Review

The table 3.1 contains a collection of the papers that have been used to conduct the literature review. The process that led to the selection of these papers is thoroughly discussed in the methodology section (Paragraph 2.1.1) and visually outlined in the PRISMA diagram (Figure 2.1). This approach ensures a structured and transparent selection process, offering a comprehensive overview of the research landscape relevant to the study.

This table provides a comprehensive collection of comments for each paper, offering an overview of the topics covered in various research studies. The table serves as a framework to identify key themes and insights discussed in each paper, particularly in the domain of token models, blockchain systems, decentralized finance and taxonomy in distributed ledger systems. The selected papers address a wide range of issues, from regulatory challenges and the classification of blockchain technologies to the development of token-based ecosystems and security token offerings. The collection of papers presented in this table largely revolves around the taxonomy and classification of blockchain systems and crypto tokens, with a focus on establishing clear and structured frameworks. Many of the papers emphasized the importance of defining and standardizing terms within the blockchain ecosystem, particularly in relation to decentralized finance and token-based ecosystems. By developing these taxonomies, the studies aim to provide a better understanding of the growing variety of tokens and their respective roles within blockchain networks. The research covers the development of token ecosystems and challenges in creating sustainable models for blockchain startups. It also explores security token offerings (STOs), focusing on compliance and regulatory aspects. In terms of blockchain infrastructure, the studies review consensus mechanisms and their impact on security, helping stakeholders choose suitable protocols for specific use cases. There is a common goal of establishing frameworks and guidelines that not only clarify the technical aspects of blockchain and token systems but also address the broader economic and legal implications. The research often underscored the necessity for collaboration between developers, investors and regulators to foster innovation while ensuring compliance and security in the blockchain ecosystem. In doing so, these papers contributed significantly to the ongoing debate on how to effectively implement and govern decentralized systems.

Title	Author	Journal	Year	Comment
Taxonomy and Universal Success Parameters of Token Models in Distributed Ledger Systems	Toepffer, Philip and Thatmann, Dirk	2020 2nd Conference on Blockchain Research and Applications for Innovative Networks and Services, BRAINS 2020	2020	Addresses taxonomy from three primary perspectives: regulatory authorities, practitioners, and academics. Collects various studies that propose nomenclature, often in disagreement with one another.

Title	Author	Journal	Year	Comment
A taxonomy for decentralized finance	Puschmann, Thomas and Huang-Sui, Marine	International Review of Financial Analysis	2024	Discusses the challenges of defining a taxonomy for decentralized finance. Provides a detailed description of the steps involved, using the example of Nickerson's methodology.
A Taxonomy for Characterizing Blockchain Systems	Alzhari, Fouzia E. and Saeedi, Kawther A. and Zhao, Liping	IEEE Access	2023	Provides a taxonomy for crypto tokens and token systems. Offers a structured analysis to help understand the various types of tokens and their respective systems.
Crypto Tokens and Token Systems	Schwierskowski, Jan and Pedersen, Asger Balle and Beck, Roman	Information Systems Frontiers	2024	Conducts a targeted analysis to classify different types of tokens and their characteristics. Emphasizes the importance of a clear taxonomy in the growing field of blockchain technology.
Decrypting distributed ledger design—taxonomy, classification and blockchain community evaluation	Ballandies, Marc C. and Dapp, Marcus M. and Pournaras, Evangelos	Cluster Computing	2022	Provides a taxonomy for crypto tokens and token systems. Offers a structured analysis to help understand the various types of tokens and their respective systems.
Development of a Blockchain Taxonomy	Weninger, Simon and Schuh, Günther and Fischer, Vincent	2019 IEEE International Conference on Engineering, Technology and Innovation	2019	Provides a taxonomy for crypto tokens and token systems. Offers a structured analysis to help understand the various types of tokens and their respective systems.
Proposal for a Comprehensive (Crypto) Asset Taxonomy	Ankenbrand, Thomas and Bieri, Denis and Cortivo, Roland and Hoenener, Johannes and Hardjono, Thomas	2020 Crypto Valley Conference on Blockchain Technology (CVCBT)	2020	Provides a taxonomy for crypto tokens and token systems. Offers a structured analysis to help understand the various types of tokens and their respective systems.
Understanding token-based ecosystems—a taxonomy of blockchain-based business models of start-ups	Tönnissen, Stefan and Beinke, Jan and Teuteberg, Frank	Electronic Markets	2020	Provides a taxonomy for crypto tokens and ICO.
Tarzan and chain: exploring the ICO jungle and evaluating design archetypes	Bachmann, Nina M. and Drasch, Benedict and Fridgen, Gilbert and Mitsch, Michael and Regner, Ferdinand and Schweizer, André and Urbach, Nils	Electronic Markets	2022	Provides a taxonomy for crypto tokens and ICO.
A taxonomy of blockchain consensus methods	Nijsse, Jeff and Litchfield, Alan	Cryptography	2020	Provides a taxonomy for blockchain consensus methods.
Guidelines: For enquiries regarding the regulatory framework for initial coin offerings (ICOs)	Eidgenössische Finanzmarktaufsicht	FINMA	2018	Guidelines issued by the Swiss Financial Market Supervisory Authority (FINMA) in 2018.

Title	Author	Journal	Year	Comment
Security token offerings	Lambert, Thomas and Liebau, Daniel and Roosenboom, Peter	Small Business Economics	2022	Describes in detail the specifics of security token offerings.
Signaling in the Market for Security Tokens	Kreppmeier, Julia and Laschinger, Ralf	Journal of Business Economics	2023	Describes in detail the specifics of security token offerings.
A taxonomy of token models and valuation methodologies	Jose Maria Macedo	Medium	2019	Provides a taxonomy for token types (grey literature).
The Superclasses of Assets Revisited	Greer, Robert	Winter 2018 GCARD	2018	Revisits the classification of investable assets.

Table 3.1: Caption of the Table to appear in the List of Tables.

3.2. Literature Analysis: DLT System and Token

In the field of literature, the most frequently employed methodology for classification is that proposed by Robert C Nickerson and Muntermann (2013), as it is specifically tailored to classification in technological studies. The process structure for achieving taxonomy is outlined below.

The procedure used by Robert C Nickerson and Muntermann (2013) to create a taxonomy is structured in seven key steps and follows a systematic and methodological approach.

1. **Meta-characteristic Determination**: In the initial phase of the procedure, the meta-characteristics of the taxonomy are determined based on their purpose. This is accomplished by conducting a systematic and comprehensive analysis of the existing literature, which enables the identification of the relevant characteristics to be included in the taxonomy;

2. **Termination Conditions**: In the second step, the termination conditions for the taxonomy development procedure are specified. In particular, three termination conditions are established by Robert C Nickerson and Muntermann (2013):

    - In each dimension, at least one object must be identified for each characteristic;
    - No new dimensions or characteristics are required to be included in the final iteration;
    - No characteristic or dimension should be altered in the final iteration.

3. **Conceptual-Empirical Deductive Approach**: A deductive conceptual-empirical approach is implemented in the passage from three to six. This entails a thorough

examination of the text and the deduction of the appropriate dimensions and characteristics. Particularly:

- **Step 4**: Conceptualisation of the characteristics and dimensions of the objects;
- **Step 5**: Examine the objects to identify these characteristics and dimensions;
- **Step 6**: Develop or restore the taxonomy by grouping the characteristics by dimensions.

These steps are repeated iteratively until the termination conditions are not met. During this process, nomenclature may evolve and require adjustments. For example, a characteristic that is initially classified in one dimension may be placed in another dimension based on subsequent iterations.

4. **Taxonomy Validation** : This is accomplished by employing an empirical-conceptual approach that employs empirical data to verify and validate the developed taxonomy;

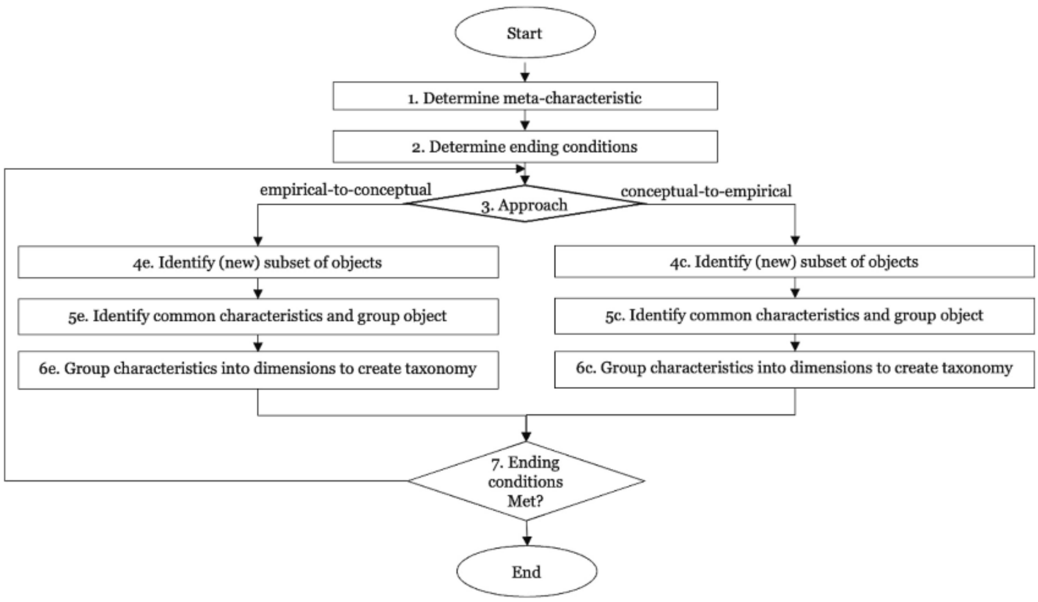


Figure 3.1: Taxonomy development process according to (Nickerson et al., 2013) used in Puschmann and Huang-Sui (2024)

Puschmann and Huang-Sui (2024) posits the following as the fundamental characteristics of an effective taxonomy:

1. **Conciseness**: The taxonomy employs a restricted number of attributes;

2. **Robustness**: The taxonomy is defined with an adequate number of attributes to enable the identification of the objects of interest.+;
3. **Comprehensiveness**: The taxonomy has the capacity to categorise all objects that are currently known within the pertinent domain;
4. **Extensibility**: The taxonomy can be expanded to include new types of objects and attribute values;
5. **Explanatory Power**: The taxonomy comprises attributes that offer meaningful explanations of the objects' essence, thereby facilitating the comprehension of future objects, rather than modelling every conceivable detail.

Therefore, the variability that is achieved during the taxonomy development process is contingent upon the statistical field that has been selected and the median-characteristics that have been selected. The statistical field is frequently populated by a collection of crypto-related start-ups that have either completed or are preparing to complete ICOs.

Numerous sources have been analysed and revised in the review of the terminologies available in scientific literature. The methodology employed involved the search for a variety of papers through portals that specialise in the collection of scientific articles, particularly Scopus. A substantial number of papers were identified by employing specific keyword phrases. Subsequently, these documents were subjected to an initial filter based on the title and subsequently on the abstract.

It is evident that there are numerous ways to define a taxonomy, which are primarily influenced by the paper's objective. The objective of our research was to develop a current taxonomy picture that focused on tokens, namely the tokenomics, and macro cryptographic project systems. As a result, only papers that focused on the definition of the fundamental characteristics of these two aspects were analysed. Studies that concentrate on other topics, such as ICOs, precisely in the papers by Bachmann et al. (2022) and Tönnissen et al. (2020) or consensus mechanisms, precisely in the paper by Nijsse and Litchfield (2020), were excluded due to the fact that they yield results that differ from those of interest.

After the initial stage of selecting papers that proposed a taxonomy that was consistent with our objective was completed, a detailed analysis of the proposed taxonomies was conducted. The fundamental characteristics of these taxonomies have been used to categorise them. Frequently, similar expressions are encountered with a variety of terminologies. It was possible to identify the most common intrinsic characteristics by conducting a detailed analysis of the terms used and their descriptions in each paper. The table 3.2 has been developed in order to summarize the factors that are frequently included in taxonomies. Therefore, these characteristics will be discussed, with an emphasis on the reasons that led to their selection.

It is clear that numerous economies share contact points. In addition to these fundamental principles, the authors of the papers have incorporated the characteristics that they consider to be the most significant in defining the crypto landscape. However, there are numerous differences among the taxonomies, suggesting that a unified taxonomy is still a long way off. Additionally, while numerous papers aspire to define token classification, the primary focus frequently shifts from the structural characteristics to the strategic characteristics of projects and startups in the crypto space. Multiple viewpoints lead to distinct results, both of which are valid, making it difficult to determine which is the more accurate. However, our study proposes a more detailed examination of structural characteristics in comparison to strategic ones, in accordance with the initial objective of our research.

This analysis demonstrates the complexity and diversity of taxonomies in the field of cryptography and underscores the importance of a rigorous methodology for defining a taxonomy that is both useful and relevant to the scientific and industrial community.

After an in-depth comparison of numerous papers, it has been determined that paper by Alzhrani et al. (2022) embodied all of the fundamental characteristics and exhibits a particularly comprehensive and effective taxonomy. For this reason, the paper was used as a reference and is being used in this study as a guide to describe taxonomies.

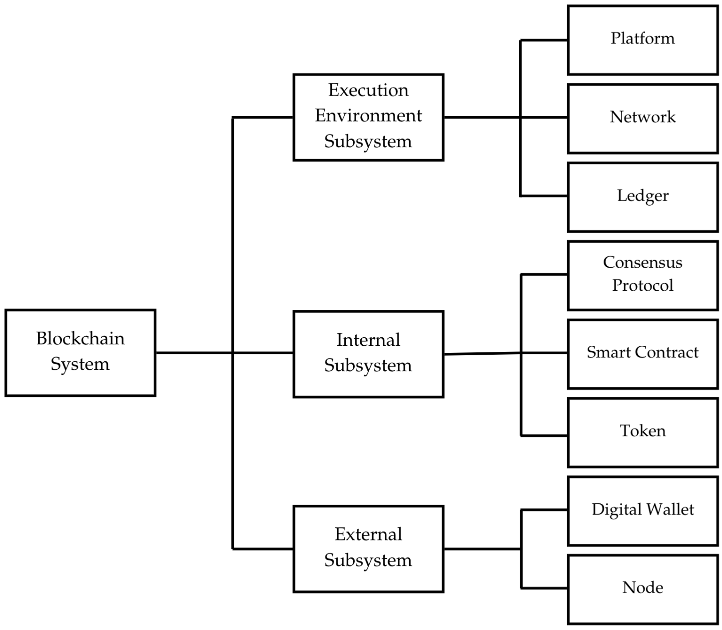


Figure 3.2: Blockchain System classification by Alzhrani et al. (2022)

As can be observed from the graph 3.2, a blockchain system can be characterised by a variety of dimensions. Due to the significant complexity and comprehensiveness of taxonomy, only the characteristics that are intrinsic to the initial objective have been selected. Therefore, the internal system, which more precisely defines tokenomics, and the executive system, which is intended as the macro system of the crypto project, are the relevant aspects. The technical aspects of how a blockchain project interacts with the external world and users are thoroughly detailed in the External Subsystem.

3.2.1. Key DLT and Token Dimensions

In comparison to the other analysed taxnomies and the paper by Alzhrani et al. (2022), the following section will address the primary variables that characterize blockchain systems and their tokens, as illustrated in Table 3.2.

The review of available taxonomies has led to the creation of Table 3.2, which summarizes all the fundamental characteristics defining Distributed Ledger Technology systems and tokens.

As highlighted in Table 3.2, the paper by Schwiderowski et al. (2024) stands out as one the most comprehensive and precise taxonomy in terms of the intrinsic characteristics of tokens. In contrast, the work by Ballandies et al. (2022) is notable for its thoroughness on DLT system side, covering nearly all of the characteristics listed, with fiew exceptions.

Following an in-depth analysis of these papers, it is also important to acknowledge the contribution by Alzhrani et al. (2022). The taxonomy proposed by Alzhrani et al. (2022) not only includes the attributes analyzed and presented in Table 3.2, but also introduces additional relevant characteristics pertaining to blockchain projects and their associated tokens. The authors of this paper have provided the most comprehensive work in the academic literature, developing a taxonomy that spans multiple levels of analysis, capturing a wide range of features across the blockchain ecosystem. The following section will describe the main characteristics presented in the table 3.2.

Characteristics	Ballandies et al. (2022)	Toepffer and Thatmann (2020a)	Schwiderowsk et al. (2024)	Wieninger et al. (2019b)	Ankenbrand et al. (2020a)	Alzhrani et al. (2022)
DLT System						
Data Structure	X	X				X
Origin	X		X	X		X
Address Traceability	X			X		X
Fiality	X				X	X
Proof	X	X				X
Write Permission	X	X				X
Validate Permission	X		X	X		X
Consensus Fee	X	X	X	X		X
Read Permission	X	X		X		X
Action Permission	X					X
Action Fee						X
Possibility of Change				X	X	X
Regulatory		X			X	X
Token						
Trasferability	X	X			X	X
Burn	X		X		X	X
Supply	X		X		X	X
Fugibility		X	X		X	X
Divisibility			X			X
Rights		X	X			X
Token Type		X	X	X		X

Table 3.2: Summary of DLT System and Token Characteristics

Data Structure This characteristic refers to the mechanism by which data and information are recorded within the distributed ledger. The main and most popular solution is definitely the Blockchain technology, that is a sequence of blocks joined together forming an immutable chain. On the other there are other types of solutions such as DAG mechanisms, SideChains and others. These solutions, in particular, are used because they improve the scalability of the network. As highlighted in Table 1 this is an intrinsic system aspect rather than a feature referring to cryptographic tokens. Both papers by Ballandies et al. (2022) and by Toepffer and Thatmann (2020b) included this attribute in the taxonomy proposed by the authors of the papers. In particular, in the paper by Ballandies et al. (2022) the term "data structure" was precisely used. This term was considered more precise and comprehensive, which is why this terminology was included in the table. Indeed, in the paper by Toepffer and Thatmann (2020b) this peculiarity was referred to by the terminology "chain type", but the concept illustrated is the same.

Origin This aspect refers to who is in charge of managing the distributed ledger and clearly indicates the layer type of the analyzed project. This feature can take several values:

- Native: e.g, Blockchain such as Ethereum and Bitcoin that maintain the distributed ledger autonomously by taking care of security and network protocols;
- External: e.g, Arbitrum which, being built on Ethereum, delegates security management to the latter and only takes care of transactional processing;
- Hybrid: if systems combine a distributed ledger from another DLT system with their own distributed ledger.

As shown in table 3.2, this feature is included in the taxonomies porposed by Ballandies et al. (2022), by Schwiderowski et al. (2023) and by Wieninger et al. (2019b).

Address Traceability This aspect is strongly related to the concept of transparency, one of the cornerstones of the Blockchain landscape. Indeed, address traceability indicates how easily transactions related to the same identity can be identified and tracked within the blockchain. This feature is critical when classifying Blockchain systems and is discussed in both papers by Ballandies et al. (2022) and by Wieninger et al. (2019a). Within Table 3.2, the terminology adopted in the paper by Ballandies et al. (2022) is used for this characteristic: "Address Traceability".

Finality This feature is strongly related to the consensus algorithms that govern the transaction validation process of the Blockchain in question. In particular, the value of this aspect can be twofold: instantaneous or probabilistic. The latter includes the PoW and Pos validation mechanisms, since consensus in these cases is achieved through a certain degree of trust.

"Finality" has been considered as a separate feature from the feature named in Table 1 as "proof" since the latter simply refers to the type of consensus mechanism used by the Blockchain network under consideration. "Finality" instead, is closely related to the validation algorithm but refers to the immutability of the data recorded on the Blockchain. This feature was covered in the papers by Ballandies et al. (2022) and Ankenbrand et al. (2020b).

Proof As mentioned earlier, it simply refers to the various types of transaction consensus algorithm used by the various Blockchains. The main mechanisms are PoW and PoS (hence the name of the feature) but there are also other variants such as Delegated Proof of

Stake (DPoS) and Proof of Authority (Poa). This aspect has been covered in both papers by Ballandies et al. (2022) and by Toepffer and Thatmann (2020b). In particular, the terminology used to mention this feature is that one reported by Toepffer and Thatmann (2020b).

Write Permission This aspect is also analyzed within papers by Ballandies et al. (2022) and by Toepffer and Thatmann (2020b). Specifically, the term "write permission" refers to the degree of permission users have to transcribe data into the distributed ledger of each Blockchain. Going into detail this parameter can have two values: restricted or public. If the action of writing data to the distributed ledger is open to all, the value will be "public" if, on the other hand, access is restricted, the value will be conversely "restricted".

Validate permission This feature can be confused with the feature analyzed earlier: "proof". In this case, the reference is not on what type of block validation mechanism is used but rather on who has permission to validate transactions before they are written to the distributed ledger. This feature is presented in papers by Ballandies et al. (2022), by Schwiderowski et al. (2024) and by Wieninger et al. (2019a). It can assumes two different values: restricted or public, depending on the degree to which participation in the process in question is restricted.

Consensus fees This feature is addressed in the taxonomies proposed by almost all the selected papers, particularly in papers by Ballandies et al. (2022), by Toepffer and Thatmann (2020b), by Schwiderowski et al. (2024) and by Wieninger et al. (2019a). According to the nature of the project, validators may or may not receive the consensus fee. Consequently the value of this feature can be twofold: yes or no. instead of acting primarily as a fee for revenue generation, it operates as an incentive mechanism designed to boost both the usage and user base of the blockchain in question.

Read permission As noted by Wieninger et al. (2019a), this aspect is often referred to as "Read rights". In particular, it refers to the level of access granted for reading the contents of validated transactions. This feature is presented in the taxonomies proposed in papers by Ballandies et al. (2022), by Toepffer and Thatmann (2020b) and by Wieninger et al. (2019a). Again, the value can be twofold: restricted or public.

Action permission As reported in paper by Ballandies et al. (2022) this feature referred to who has the authority to perform a specific action. This paper has shown the example of Bitcoin, where anyone is allowed to create private keys in order to send and receive digital tokens. This aspect, as shown in Table 3.2, is covered only by the paper by Ballandies et al. (2022).

Action fees This feature was discussed in depth by Ballandies et al. (2022), who noted that in certain blockchain projects, specific actions require the payment of a fee. A common example is the transfer of funds between wallets, which typically incurs a transaction fee.

Possibility of change This feature reflects one of the fundamental principles of Blockchain technology: immutability. As pointed out in the paper by Wieninger et al. (2019a), immutability refers not only to ensuring that transactions are permanent and unchangeable, but also concerns the ability to evolve or adapt the platform through modifications or the addition of new features. These changes, however, cannot be implemented arbitrarily; they require consensus to be reached among members of the project community. This consensus is usually achieved through mechanisms such as Hard Fork or Soft Fork, which allow for significant or gradual changes to the Blockchain, respectively, while maintaining the consistency and integrity of the system. This aspect, as well as in the paper by Wieninger et al. (2019a) turns out to be present and discussed in the paper by Ankenbrand et al. (2020b).

This feature exemplifies one of the core principles of blockchain technology: immutability. As highlighted by Wieninger et al. (2019a), immutability not only guarantees that transactions remain permanent but also involves the ability to evolve or enhance the platform through updates or the introduction of new functionalities. However, these modifications cannot be made arbitrarily; they require consensus among the members of the project community. Such consensus is typically achieved through mechanisms like Hard Forks or Soft Forks, which facilitate either substantial or incremental changes to the blockchain while preserving the system's integrity and coherence. This aspect is also explored in the work by Ankenbrand et al. (2020b), where the governance and consensus mechanisms that enable controlled evolution of blockchain platforms are further discussed.

Transferability This feature is of great importance as it relates to the property of assigned tokens. Specifically, a token can be transferable if it can be exchanged between two wallets, enabling the transfer of ownership of the corresponding asset. In contrast, a token is non-transferable if it cannot be exchanged. An example of a nontransferable token, as highlighted in the paper by Ankenbrand et al. (2020b), is that used in giveaways. This aspect is analyzed not only in the paper by Ankenbrand et al. (2020b) but also in the papers by Ballandies et al. (2022) and by Toepffer and Thatmann (2020b).

Burnability The process called "burn" involves the destruction of a certain number of tokens within a specific project, thus reducing the supply of tokens in circulation. This mechanism is not present in all Blockchain projects and is closely related to the strategy of the project itself. Often, the practice of burning tokens leads to an increase in their value, as the decrease in supply tends to drive up the price. In many cases, the burn process is activated only when certain specific events occur, making it a strategic component of token value management. This feature is included in the taxonomies proposed by papers by Ballandies et al. (2022), by Schwiderowski et al. (2024) and by Ankenbrand et al. (2020b).

Supply Each Blockchain project, in its protocol, specifies the number of tokens in circulation. There are two main options: the supply can either be "capped," meaning it is fixed with a predetermined maximum limit, or it can be "uncapped," where no upper limit is imposed on the total supply. Supply is one of the primary pieces of information that accompanies the issuance of tokens; however, it is not always considered as a determinant for classifying the various families of tokens. Indeed, supply is discussed only in papers by Ballandies et al. (2022), by Schwiderowski et al. (2024) and by Ankenbrand et al. (2020b).

Fungibility The fungibility of a token is one of the primary aspects to consider when analyzing tokens. At the core of this characteristic is the concept of interchangeability: a FT is defined when two wallets can exchange two tokens of the same project without causing any change in the value of the wallet itself; in contrast, NFTs are unique, in particular, all NFTs belonging to a given project potentially have a different value among them. The fungibility feature is presented within the taxonomies in papers by Toepffer and Thatmann (2020b), Schwiderowski et al. (2024) and by Ankenbrand et al. (2020b).

Divisibility This feature is discussed exclusively in the paper by Schwiderowski et al. (2024), where it is identified as characteristic of Payment tokens. Specifically, divisibility refers to the ability to split tokens into smaller units. For instance, Bitcoin, allows users to buy, sell or trade fractions of a token, enabling more flexible and granular transactions. This divisibility is crucial for facilitating everyday exchanges and microtransactions, making these tokens more versatile for various use cases.

Rights This feature, discussed in both papers by Toepffer and Thatmann (2020b) and by Schwiderowski et al. (2024), indicates whether the token in question confers rights or decision-making powers on its holders. In particular, many tokens provide access to decisions about the governance of a project. From this perspective, the community takes a central role in decision-making processes, influencing project strategy and governance. This fully reflects one of the fundamental principles of Blockchain projects: decentralization, where decisions are made by project users rather than by a central entity.

Token Type As highlighted in the paper by Toepffer and Thatmann (2020b), the three token types recognized by authorities, utility token, payment token and security token, are commonly used to classify tokens. This distinction, examined in detail earlier, serves as a simplified framework for categorizing tokens. It is a prevalent feature in nearly all the papers analyzed, with the exception of those by Ballandies et al. (2022) and Ankenbrand et al. (2020b), where this specific classification is not addressed.

The taxonomy proposed by Alzhrani et al. (2022) encompassed not only the attributes analyzed above and presented in Table 3.2, but also included additional relevant characteristics of blockchain projects and their associated tokens. Below are some of these, considered particularly relevant.

Smart contract Specifically, the component level is divided into external components and internal components. In the section on internal components, the focus is on Smart Contracts, a key attribute of Blockchain technology. A classification of blockchain projects is made by distinguishing between different types of smart contracts, which are analyzed across five key components: Hosting Network, Type, Interaction, Events, and License. Among these, Type and Interaction stand out as the most significant factors, offering deeper insights into the functionality and structure of the smart contracts used within various blockchain ecosystems:

- **Type**: refers to the nature of the smart contract, which can vary, for example, among legal, token type, organizational and other categories of contracts;
- **Interaction**: distinguishes between two variants: Machine-to-Machine and Machine-to-Human. In the former case, interaction occurs exclusively between nodes and devices, while in the latter there is human involvement.

Token expiry Another important feature regarding the properties of tokens is precisely the expiration of the token. In particular, a token can have a finite lifespan or as in most cases it can have no expiration date.

Ledger architecture This attribute is particularly significant as it specifies the type of ledger on which data and transactions are recorded. Notably, it does not focus on the data structure itself, meaning there is no distinction made between native, external, or hybrid networks. Instead, the emphasis is on the architecture of the ledger. More specifically, a ledger can be categorized as single, multi, or interoperability-based, reflecting the different ways data is organized and managed across blockchain networks. This classification underscores the role of the ledger's structure in determining how transactions are processed and stored:

- **Single-Ledger**: is an architecture that is initially public and permissionless, but adaptable to private and hybrid contexts;
- **Multi-Ledger**: is an architecture designed for private and federated networks, allowing confidential transactions;
- **Interoperability-Based**: is an architecture created to solve interoperability problems between blockchains with single or multiple ledger-based architectures.

3.3. Token Types Taxonomy Analysis

The taxonomy analysis reveals that the cryptocurrency landscape is characterized by a multitude of variables, which are organized into various categories. Going into specifics and trying to define the characteristics of tokens, one relevant variable is the Token Archetype. This variable will be used to specify the token's actual functionality, allowing it to be categorised within a variety of subclasses. Asset tokens, utility tokens, payment tokens and stablecoins are examples of tokens that are widely used. However, these attributes are the result of a variety of interpretations that the researchers have made, and they are not the result of a structured and objective method. Numerous studies have proposed their own versions of these attributes, and the same has been achieved by grey sources. The market's uncertainty increases by the absence of a structured and regulated reference grid. Therefore, the objective of this paragraph is to expose, contrast, and illustrate the differences and contact points among the various token types proposed.

The paper by Toepffer and Thatmann (2020a) highlights a diverse range of proposed nomenclatures for token classification, many of which are often in disagreement with each other. Consequently, their research adopts the framework developed by Outlier Ventures[1], which categorizes tokens with the aim of establishing best practices in the field.

The cryptographic tokens are divided into three types:

[1]https://outlierventures.io/

- **Asset token**: it symbolises a wide range of assets, including traditional assets, digital assets, and commodities;
- **Usage token**: it provides access to digital services, offering a range of utilities through its platform;
- **Work token**: It grants the holder the ability to actively participate in the network, with the token's utility defined by the decentralized governance of its community.

Although this taxonomy has some interesting insights, it has certain drawbacks as it does not fully and effectively consider all the types of tokens available in the market.

Several papers, such as that by Wieninger et al. (2019b) and by Toepffer and Thatmann (2020a), have instead adopted the categorisation of the Swiss FINMA (Finanzmarktaufsicht, 2018). This last one, dating back to 2018, categorises tokens into the following main groups:

- ***Cryptocurrency**: "a token whose main function is to operate as a unit of a general payment system" (Finanzmarktaufsicht, 2018).*
- ***Utility Token**: "a token that serves as a kind of admission ticket to an application, such as a digital service, comparable to a medium of exchange" (Finanzmarktaufsicht, 2018).*
- ***Asset Token**: "a token whose main function is, for example, profit sharing or share rights. An example project for this type of token is the Kabuni project" (Finanzmarktaufsicht, 2018).*

Among the various papers proposing a taxonomy of tokens, the study by Schwiderowski et al. (2023) conducted a targeted analysis to specifically classify the different types of tokens and their characteristics. The approach used is to categorise cryptocurrencies into three different families, specifically utility, payment and asset tokens. Various subgroups are subsequently included and specifically defined within these categories. The suggested division consists of the the following:

- *"Asset tokens are crypto tokens that are linked to physical or digital assets (financial and non-financial). They can represent security and investment tokens as well as digital registries"* (Schwiderowski et al., 2023);
- *"Payment tokens are crypto tokens used for making digital payments"* (Schwiderowski et al., 2023);
- *"Utility token: Tokens that provide a certain utility to users (such as access rights,*

> *member- ship rights, or identification and authentication), or that serve as rewards"* (Schwiderowski et al., 2023).

Within the asset token category, there are tokens related to security, investments, derivatives, debt, equity and more. These tokens are related to the financial sector and enable to obtain ownership rights associated with the possession of an asset, acquired with the aim of generating profits. Several works, such as the paper by Lambert et al. (2022), provided a similar definition of this asset class, describing security tokens in the following manner: *"A security token is a digital representation of an investment product, recorded on a distributed ledger, subject to regulation under securities laws"* (Lambert et al., 2022).

This definition is also applicable to other papers, such as that by Kreppmeier and Laschinger (2023), which incorporated it into their research. Consequently, the fundamental characteristic of this category is that it is classified as investment products, providing access to potential future returns or profits. The utility token category encompasses the majority of tokens due to their diverse functionalities. These tokens are designed to provide access to a particular system, enable participation in voting and consensus mechanisms, and support a range of other functions within their respective ecosystems. The development of a detailed and stable taxonomy is complicated by the mutable nature of these tokens, as the creation of their characteristics and functions is a decision made by the project's developers and it is described in the white paper. On the other hand, payment tokens include tokens defined in cryptocurrencies and stablecoins, for instance. They are defined as "cash equivalent on a blockchain" in the paper by Lambert et al. (2022). These types of tokens are capable of serving as a medium of exchange and they keep numerous characteristics of traditional currencies. Further investigation will be conducted subsequently.

It was decided to complement the taxonomy derived from academic literature with material from grey literature. In particular, following a review of the articles available in various forums through several search engines, the article "A taxonomy of token models and valuation methodologies" by Macedo (2018) was selected as the representative article. This article adopted a perspective similar to that emerging from academic literature, with scientific rigour and methodology, but it provided a more contemporary perspective on the crypto landscape. The proposed nomenclature is the result of the translation by Greer (2018), into the blockchain context. This work provided a rigorous definition of what represents an "investable asset class".

It is argued that patrimonial activities are divided into three primary categories: capital assets, consumable/transformable assets, and store of value assets.

- **Capital assets**: such as stocks and bonds, serve as an ongoing source of value. For stocks, this value is represented by a stream of dividends that may persist indefinitely, whereas for bonds, it is represented by a stream of interest. The theoretical evaluation of this asset class involves the application of the DCF method, which involves determining the current value of future cash flows;

- **Consumable/transformable assets**: are physical commodities, such as oil, that have an intrinsic economic value and can be converted into other products. In contrast to Capital Assets, these assets do not generate a continuous flow of value and cannot be evaluated using the DCF. Instead, their evaluation is conducted through demand and supply models that consider market dynamics and resource availability;

- **Store of Value Assets**: are assets that cannot be consumed but maintain an intrinsic value over time. Valuables and works of art are included in this category. For instance, coins do not generate cash flows; rather, they preserve their value as a means of exchange and value accumulation. In the same way, works of art do not generate wealth; however, they may increase in value over time and serve as a means of conserving wealth. The evaluation of these assets is primarily based on their perceived value and rarity, rather than traditional financial models.

Therefore, as shown in Figure 3.3, Jose Maria Macedo transferred this asset class to:

1. **Cryptocapital**: which is the equivalent of capital assets with an ongoing source of value. Tokens are divided into Security and Work (Utility) categories;

2. **Cryptocommodities**: Crypto assets that are non-productive and do not generate an ongoing stream of value. Their primary function is that of cryptocurrency.

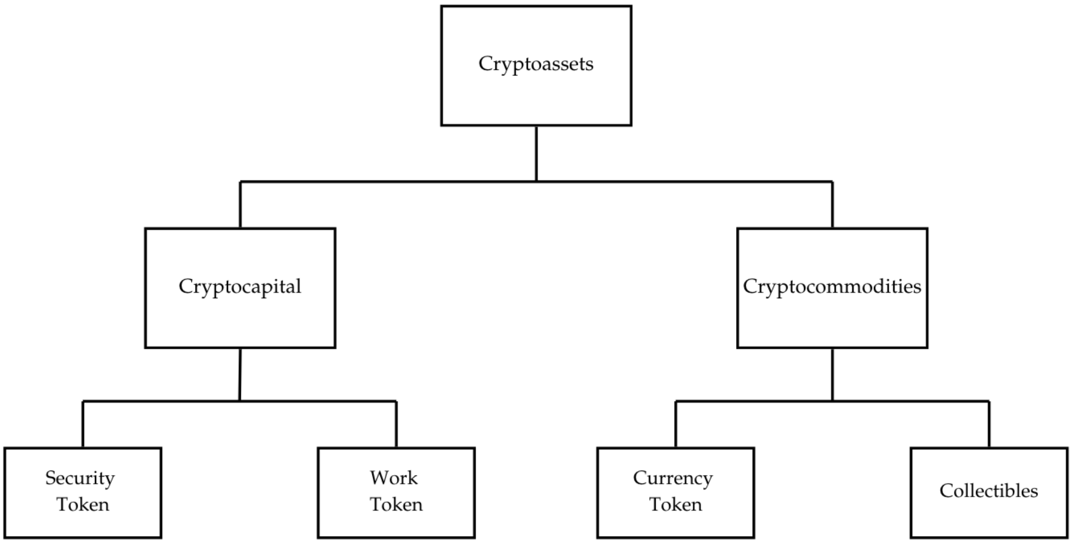


Figure 3.3: Taxonomy developed by Macedo (2018)

In this case, the discriminant that divides security and work token is the required level of participation, which is passive for the first group and active for the second. Tokens associated with debit, equity and derivatives may be located within security tokens, employing an approach similar to that of asset tokens in literature. In contrast, work tokens are provided by an entity in exchange for the right to deliver potentially profitable work to the token network, such as staking and governance. Within currency tokens, which are crypto commodities, it is feasible to locate tokens that comply to one or more of the three pillars of currency. In this instance, the author emphasises the significance of currency function, conducting a taxonomy based on this factor. One example of this is the distinction between payment tokens and stablecoins, in that the former are used as a medium of exchange, while the latter are used as a store of value.

3.4. Regulation

3.4.1. Paper Review

The table 3.3 contains a collection of the papers that have been used to conduct the literature review. The process that led to the selection of these papers is thoroughly discussed in the methodology section (Paragraph 2.1.1) and visually outlined in the Taxonomy PRISMA diagram (Figure 2.1). This approach ensures a structured and transparent selection process, offering a comprehensive overview of the research landscape relevant to the study.

These papers primarily explore crypto-asset regulation and accounting practices for digital assets. Some studies focus on regulatory frameworks, such as the European Union's proposal on Markets in Crypto-Assets (MiCA), assessing whether these regulations enhance legal certainty and foster wider adoption. Others delve into the accounting treatment of various crypto-assets under different standards, such as International Financial Reporting Standards (IFRS) and Generally Accepted Accounting Principles (GAAP), providing comprehensive guidelines for payment tokens, utility tokens, and security tokens.

One study examines the financial reporting practices of firms dealing with digital assets, highlighting the challenges and inconsistencies across global financial statements. Another paper specifically addresses DLT-based token classification, offering definitions and suggesting appropriate accounting treatments for DLT tokens.

Overall, these papers provide valuable insights into the evolving landscape of crypto-assets, from both a regulatory and accounting perspective, offering practical solutions and analyses of current global practices.

This summary encapsulates the themes of regulation, accounting frameworks and practical challenges discussed in these papers.

Summary of Crypto-Asset Taxonomy and Accounting Papers

Title	Author	Journal	Year	Comment
Markets in crypto-assets regulation: Does it provide legal certainty and increase adoption of crypto-assets?	Linden, Tina and Shirazi, Tina	Financial Innovation	2023	Discusses the European Union's proposal for a Regulation on Markets in Crypto-Assets.
Cryptoassets: Definitions and accounting treatment under the current International Financial Reporting Standards framework	Parrondo, Luz	Intelligent Systems in Accounting, Finance and Management	2023	Provides a comprehensive definition of cryptoassets for accounting purposes, focusing on payment tokens, electronic money (e-money) tokens, utility tokens, and security tokens.
Accounting For Digital Assets	Jackson, Andrew and Luu, Stephen	Australian Accounting Review	2023	Covers the practice of the small number of firms globally reporting digital assets on financial statements, assessing potential treatments under current GAAP.
DLT-based Tokens Classification towards Accounting Regulation	Parrondo, Luz	FEMIB	2020	Offers a definition, classification, and guidance for the accounting treatment of DLT-based tokens.
Financial reporting for cryptocurrency	Luo, Mei and Yu, Shuangchen	Review of Accounting Studies	2022	Compares and contrasts US and international accounting and financial reporting practices for cryptocurrency, analyzing the financial statements of 40 global companies with exposure to cryptocurrencies.

Title	Author	Journal	Year	Comment

Table 3.3: Caption of the Table to appear in the List of Tables.

The current state of the regulations is characterised by extreme uncertainty and instability regarding a defined and unifying cryptoasset taxonomy. The challenge in establishing this classification is the incomplete definition of the various types of crypto and tokens. The official entities face complications in expanding the current IFRS standards or creating new ones ad hoc, as the discriminants and characteristics that describe the world of crypto and blockchain are not clearly defined.

This objective was embraced by the competent European bodies, particularly the European Financial Reporting Advisory Group (EFRAG), in the form of a first Discussion Paper (DP). In September 2020, the European Commission deliberated on an official proposal, known as the MiCA, which focused on cryptoassets that were not yet regulated.

EFRAG EFRAG is an independent organisation that provides technical advice to the European Commission regarding the adoption of IFRS in the European Union. His primary responsibility is to evaluate and recommend the adoption of IFRS standards, ensuring that they are compatible with the European context and meet the financial needs of European users.

IFRS IFRS is a collection of international accounting standards that were developed by the International Accounting Standards Board (IASB). These standards are intended to serve as a common language for business, enabling the global comparability and transparency of financial information. The IFRS are essential for international companies and are adopted by numerous countries worldwide.

MiCA The MiCA is a proposal for regulation by the European Union that aims to establish a comprehensive regulatory framework for crypto assets and cryptocurrencies. The objective is to provide legal clarity and security to crypto asset issuers and related service providers, thereby ensuring the protection of investors and the integrity of the market. The MiCA regulation was designed to provide legal certainty by stabilising a regulatory framework that encourages innovation and legal competition, thereby safeguarding contemporary investors and consumers, as specified in the paper by Linden and Shirazi (2023). MiCA was established in response to the absence of specific EU-wide regulations, the lack of clarity on EU rules concerning crypto-assets and the divergences between national regulations. MiCA attempts to address monetary policy concerns, mitigate the risks of fraud, protect consumers and investors and reduce the risks of market integrity, market fragmentation, lack of a level playing field and financial stability, in addition to reducing regulatory barriers to the use of crypto-assets.

It is of significant importance to establish fair value measurements in order to determine the value of cryptocurrencies listed in financial statements. This means that one can be certain that the accounting records accurately reflect the reality of owning cryptocurrencies. Greater clarity will enable a greater safeguard for consumers and users, as well as the providers of these services in the blockchain world.

According to the paper by Parrondo (2023), the cardinal criteria that enable the accurate classification of crypto tokens should be:

1. **Legal status**: recognition as fiat money and absence of claims against the issuer;
2. **Economic functions**: include the provision of a service or utility and the existence of investment purposes;
3. **Financial characteristics**: including the measurability of its fair value, liquidity, negotiability, fungibility and volatility.

It is essential to note that cryptoassets are not currently recognised in a universal manner by any accounting standard. The paper by Jackson and Luu (2023) addressed this issue by proposing the identification of new standards or the integration of tokens into the current definition of financial instruments. MiCA has proposed the classification of cryptoassets based on two criteria:

- **Purpose**;
- **Structure**.

This classification entails the selection of one of the criteria for token classification. Security and utility tokens will be classified first based on their purpose, while tokens that refer to an asset, such as cryptocurrency, stablecoins and other tokens, will be classified based on their structure. Conversely, it is evident that hybrid tokens are prevalent in the blockchain's dynamic and highly customisable environment.

Indeed, additional criteria may be introduced, which presents a new dilemma: which criteria should be considered? ETH is a simple and obvious example. In addition to functioning as a widely recognised payment method, ETH seamlessly incorporates utility features by facilitating the execution of decentralised applications.

"*IFRS IC (2019) described cryptocurrencies as cryptoassets with all the following characteristics: (1) a digital or virtual currency recorded on a distributed ledger that uses cryptography for security, (2) not issued by a jurisdictional authority or other party and (3) does not give rise to a contract between the holder and another party*" (Parrondo, 2023).

IFRS IC has evaluated a variety of potential solutions to represent the accounting standards of cryptoassets. This process has not yet reached a conclusion and is likely to require a significant amount of time to be completed. However, it is fascinating to observe how these entities are evolving towards the definition of the latter.

Currently, the IFRS Committee values cryptoassets as follows (Jackson & Luu, 2023):

- **Intangible assets**: adhering to the norms IAS 38, *"an identifiable non-monetary asset without physical substance"* and *"The same conclusions would be reached following US GAAP."*
- **Inventory**: adhering to the norms IAS 3, *"the IFRS IC is of the view that if an entity is holding digital currencies for sale in the ordinary course of business, the digital currency should be recognised as inventories in accordance with IAS 2"*. In accordance with the US GAAP, however, cryptocurrency may not be considered as assets because assets must be tangible, which excludes digital goods because they lack a physical form.

However, it faces challenges in accurately categorizing tokens within these classifications.A more refined approach entails aligning each token class with a definition that better reflects its legal, economic and functional characteristics. It is crucial to establish clear and effective criteria that highlight the distinctions between various cryptoassets, ensuring the creation of specific standards tailored to each category. This method allows for a more accurate and meaningful classification of tokens. Parrondo (2020) suggested four distinct criteria that may be implemented to achieve this objective:

1. Existence of a legal claim against a counterparty;
2. Intrinsic value and (therefore) functionality;
3. Stability of token value;
4. Investment risk and functional equivalence with ordinary securities.

Therefore, by employing these criteria, it was possible to establish a token taxonomy, which is divided into (Parrondo, 2023):

- *"Payment tokens" are those not holding a legal claim against a counterparty*
- *"Utility tokens" are those that have a legal claim against a counterparty, and a certain degree of token value stability and their holding should not entail investment risk.*
- *"Security tokens" should have a legal claim against a counterparty, investment risk and functional equivalence with ordinary securities.*

In the Paper by Parrondo (2023), potential solutions are proposed for the effective regulation of cryptocurrencies within the current accounting framework. Additionally, the various salient points identified by EFRAG for each category are addressed and clarified. It is exhaustive and effective in the methodology with which it addresses each detail related to the various types of tokens, employing the previous requirements. It appears that the decision to include cryptoassets in the IAS 38 (Intangible Assets) and IAS 2 (Inventories) standards is occasionally questionable and fails to accurately describe the characteristics of each individual token.

Regarding "payments tokens", it is crucial to emphasise their status as "means of exchange", which aligns them with a definition of intangible assets. The distinction between this last type and inventories, which are defined as "assets held for sale", is therefore not based on intrinsic cryptographic characteristics, but rather on the intentions of the individual who possesses them. However, the mere fact that they are a trading medium is insufficient to qualify them as equals to Cash and Cash equivalents (IAS 7), given their volatile nature. Furthermore, cryptocurrency is distinguished from cash because it is not accepted as currency and is not backed by any state or government. However, they could also be classified in this category as e-money tokens, which are defined by the MiCA as tokens that maintain a stable value by referencing no more than one fiat currency. E-money is merely one of the token types that serve as collateral for other assets, which are referred to as stablecoins. The implications of defining stablecoins as Cash are significant, necessitating new regulations that would encompass central banks, new control systems and so forth.

Utility tokens, which are tokens that possess a functionality, are undoubtedly the more variable type and are subject to modification by the creators of various projects. Due to the diversity they represent, it is difficult to establish unambiguous standards. Indeed, these latter ones are developed on an ad hoc basis and are aligned with the requirements outlined in the white paper.

EFRAG offered a few examples of these functions when defining utility tokens (Parrondo, 2023):

1. *rights to access products or services of token platform (ETH); rights to purchase or sel existing or future products or services(ETH);*
2. *rights to partial ownership of a product (NFTs);*
3. *rights to mining activities (Tezos and Livepeer token);*
4. *rights to contribute labour, effort or resource to a system (The Labor-Hour token);*
5. *rights to contribute, programme or create features of a system (Dock, MakerDAO token, Blockstack and Dfinity);*
6. *rights to decide on products, services and functionalities to be offered or deleted within the token platform (Tezos);*
7. *rights to vote on matters of governance, management and operation of token platform (MKR and Aragon network tokens).*

The most significant topic is this subgroup of cryptocurrencies, which, in addition to the high degree of personalisation or potential manipulation of tokens, is related to the possibility that the public may interpret these tokens as investment instruments. If utility tokens were interpreted in this manner, they would be comparable to security tokens, which are more similar to financial instruments, from a regulatory perspective. This uncertainty is addressed in the EFRAG DP, which emphasises that it may be challenging to determine the intrinsic value of tokens due to the typically asymmetric business models employed by entities that conduct ICOs.

Security tokens present the potential to be incorporated into the definition of financial assets under IFRS 9 and IAS 32. Therefore, there is the option to either create new standards ad hoc or modify the existing ones with regard to all of those tokens with a value similar to that of equities. The paper by Parrondo (2023) explored how certain tokens are explicitly categorized as financial assets under the IFRS definition of financial instruments. A token that is neither a derivative nor equity may still be considered a financial asset if it exists within a contractual framework that grants the right to receive currency or another financial asset. For example, a cryptoasset that provides the holder with the right to receive a financial payment would meet this criterion. Furthermore, in the United States, the Howey test is used to determine if such cryptoassets fall under securities regulations, as outlined by Linden and Shirazi (2023), underscoring the regulatory complexities surrounding these assets.

Howey Test The U.S. Supreme Court's methodology for determining whether a transaction qualifies as an investment contract is essential in determining whether an asset qualifies as a security, thereby subject to the registration requirements of the federal securities laws. A security is a financial instrument that possesses monetary value and can be traded in a financial market. It must satisfy four primary criteria:

1. **Money investment**: A financial commitment must be made, whether through monetary contributions or other valuable resources. For example, tokens earned solely through the contribution of time and expertise, without the exchange of money or assets, do not meet this criterion;

2. **Joint venture**: Investors pool their funds, with the success of the investment relying on the collective efforts of others, typically managed by a promoter or third party. This definition excludes simple bilateral agreements.

3. **Profit Expectation**: Investors must anticipate an economic return on their investment, predominantly from the efforts of others. If an asset is acquired for personal use without the intention of reselling it for profit, it does not satisfy this requirement;

4. **Derived from the efforts of others**: The investment's success must be contingent upon the expertise or management efforts of others. For instance, the acquisition of a work of art with the expectation that its value will increase does not meet this test, as the increase in value is not associated with the efforts of others.

If all of these criteria are satisfied, the transaction is classified as an investment contract and, as a result, may be subject to the registration requirements of the Securities Act of 1933 and other federal securities laws in the United States. Utility tokens, which offer access to future products or services or other benefits, are typically classified as tokens that fail this test. The SEC Chairman proposed that a significant number of PoS tokens could be classified as securities under this methodology.

Additionally, there are accounting issues that arise if the choice is made to implement the IAS 2 inventory standards and IAS 38 intangible asset standards. Indeed, The paper by Jackson and Luu (2023) discussed that:

1. *Under IAS 2, digital assets would need to be recorded initially at cost, and then subsequently measured at the lower of cost and net realisable value. Due to the acknowl- edged volatility in digital assets, increases in fair value above cost not being recognised in income may lead to useful information not being communicated to users of financial statements* (Jackson & Luu, 2023);

2. *Under IAS 38 entities can apply a revaluation model to accounting for digital assets*

> *as there is an active market. The only differences in accounting under the revaluation model is that subsequent measurement will be at fair value less any accumulated impairment losses, and upwards movements will be recorded in other comprehensive income. While reflecting upwards movements in digital asset values in the balance sheet, some commentators have argued this still does not go far enough in that it still does not adequately reflect the value of cryptocurrencies in particular, and digital assets more generally* (Jackson & Luu, 2023).

The paper by Linden and Shirazi (2023) argued that the current iteration of the MiCA regulation is unlikely to significantly accelerate the adoption of cryptoactivity within the EU financial services sector, failing to achieve the expected impact.

Inconsistencies in financial reporting can arise from differing accounting treatments across jurisdictions, potentially leading to confusion among investors and stakeholders. Harmonizing accounting standards for digital assets would improve transparency and comparability, fostering a more robust global regulatory framework.

The paper by Luo and Yu (2022) examined the financial statements of 40 global companies with exposure to cryptocurrencies and identifies substantial discrepancies and distortions in the valuation of assets, liquidity, profitability and cash-generating capacity among the companies. The need for specific accounting standards for cryptocurrencies is emphasized, advocating for a fair-value approach to valuation, where changes in value are recognized in the income statement. The potential applications of blockchain are unquestionably broad, and it is inevitable that new forms of digital assets will be introduced. In order to maintain the trust of investors, creditors and governments, regulators must act promptly to guarantee that the financial statements prepared by entities continue to accurately reflect their financial position and performance.

3.5. Taxonomy Conclusion

The results of this chapter reveal that several key characteristics consistently emerge across the majority of the papers analyzed and compared in the context of taxonomy. These findings highlight the intricate and complex nature of DLT systems and tokens, particularly with respect to the systems themselves rather than the tokens. Indeed, once a class of DLT system is identified, the characteristics of the tokens tend to show limited variation. While a unified taxonomy has yet to be established, there are academically robust proposals, such as the one presented in Alzhrani et al. (2022), that offer valuable frameworks for classification.

The analysis of token types indicates that, despite some divergences, the landscape is gradually converging toward the definition of three primary token types: Security Tokens, Utility Tokens, and Payment Tokens. Although these categories may be labeled differently across various papers and gray literature, there is a growing consensus toward more standardized definitions. However, the regulatory landscape presents a significant dilemma, as it remains neither unified nor fully structured. Different jurisdictions continue to propose varying regulations for these token types, which adds another layer of complexity to their classification and impacts how they are treated in accounting and legal contexts.

However, using a valuation methodology that focuses solely on token types would be less effective. Comparing structurally similar tokens from different DLT systems could distort the analysis or overlook crucial system-specific factors necessary for an accurate evaluation.

Recognizing the strong correlation between the value generated by a project and the value captured by its associated token, the decision has been made to focus the next chapter on valuation approaches centered around DLT systems. This shift will allow for a more comprehensive and accurate exploration of valuation, taking into account the broader system context that fundamentally influences token dynamics.

4 | Valuation

The valuation of tokens presents a significant challenge due to the complexity of accurately predicting their value, which is influenced by a combination of traditional economic factors and psychological and behavioral dynamics.

The purpose of this chapter is to provide a comprehensive and up to date review of the existing literature on token valuation. Following the approach outlined by Şoiman et al. (2023), the literature review will differentiate between cryptocurrencies and DeFi tokens, highlighting the unique considerations and insights relevant to each category.This distinction enables a more refined understanding of the valuation frameworks and methodologies applied to various types of digital assets.

Cryptocurrencies (Section 4.2), such as Bitcoin and Ethereum, are digital currencies that employ cryptographic techniques to safeguard transactions and regulate the generation of new units. These cryptocurrencies primarily serve as mediums of exchange and store of value. Bitcoin is commonly called 'digital gold' because of its limited supply and reputation as a secure investment. Ethereum possesses distinct functionality compared to Bitcoin, mostly attributed to its capacity to facilitate smart contracts, hence pushing the development of decentralised apps.

DeFi tokens (Section 4.3), such as Uniswap, are specifically designed for smart contract platforms, mostly Ethereum, to enable a variety of decentralised financial services. These services encompass loan, staking, trading, yield farming and other activities, all conducted without the involvement of centralised bodies. DeFi tokens are more than just digital currency; they provide access to complex and innovative financial networks. For example, Uniswap enables users to directly trade tokens with one another using a liquidity pool system.

In Section 4.4, the findings from the review of papers focusing on the impact of behavioral finance on token valuation will be discussed. Finally, in Section 4.5 the most significant insights from the grey literature will be presented.

4.1. Paper Review

The table 4.1 contains a collection of the papers that have been used to conduct the literature review. The process that led to the selection of these papers is thoroughly discussed in the methodology section (Paragraph 2.1.2) and visually outlined in the PRISMA diagram (Figure 2.2). This approach ensures a structured and transparent selection process, offering a comprehensive overview of the research landscape relevant to the study.

This table presents a collection of summaries and comments for a series of research papers focused on the valuation and returns of cryptocurrencies and DeFi projects. The included papers address various methodologies and key performance indicators for evaluating the value of digital assets such as Bitcoin, Ethereum, DeFi tokens and other cryptocurrencies. The scope of the papers is broad, with some emphasizing traditional financial metrics, such as Total Value Locked (TVL), Net Value of Transactions (NVT) and address-to-network ratio, while others propose more innovative approaches, like machine learning-based methods for valuation. Several papers explore the role of market sentiment, investor attention and herding behavior in influencing the price and returns of digital assets. Additionally, the table includes research investigating how volatility, adoption patterns and macroeconomic factors impact tokenomics and cryptocurrency valuations. These papers offer a mix of qualitative and quantitative analyses, often drawing comparisons to traditional financial systems while applying these insights to the rapidly evolving crypto market. Together, these papers provide a comprehensive overview of the current academic discourse on cryptocurrency valuation and the factors driving DeFi market returns, offering valuable insights into the metrics and models shaping the understanding of this dynamic market.

Summary of Research Papers on DeFi and Cryptoasset Valuation

Title	Author	Journal	Year	Comment
What drives DeFi market returns?	Soiman, Florentina and Dumas, Jean-Guillaume and Jimenez-Garces, Sonia	Journal of International Financial Markets, Institutions and Money	2023	Separates cryptocurrencies and DeFi tokens, demonstrating the correlation between BTC, ETH, and DeFi tokens. Highlights TVL (Total Value Locked) as a fundamental metric that should be divided by market capitalization.

Title	Author	Journal	Year	Comment
Decentralized Finance (DeFi) Projects: A Study of Key Performance Indicators in Terms of DeFi Protocols' Valuations	Metelski, Dominik and Sobieraj, Janusz	International Journal of Finance	2022	Identifies TVL (Total Value Locked) and GMV (Gross Merchandise Value) as key metrics for evaluating cryptocurrencies. Highlights a gap in existing literature regarding the valuation of tokens and the use of multiples.
Cryptocurrency Valuation: An Explainable AI Approach	Liu, Yulin and Zhang, Luyao	Lecture Notes in Networks and Systems	2023	Introduces the Price-Utility Ratio as an innovative approach to evaluating cryptocurrencies.
Review of Blockchain Tokens Creation and Valuation	Marin, Oana and Cioara, Tudor and Todorean, Liana and Mitrea, Dan and Anghel, Ionut	Future Internet	2023	Analyzes the macroeconomic factors impacting the market value of tokens using both qualitative and quantitative approaches.
Is there a value premium in cryptoasset markets?	Liebi, Luca J.	Economic Modeling	2022	Introduces a new metric: address-to-network.
Cryptocurrency: Value Formation Factors and Investment Risks	Pakhnienko, Olena and Rubanov, Pavlo and Girzheva, Olga and Ivashko, Larysa and , and Kozachenko, Lilia	Journal of Information Security	2022	Focuses on elements influencing the value of tokens, detailing various factors critical in determining market value.
Volatility effect on the adoption and valuation of tokenomics	Chen, Jollen and Lin, Dung-Cheng and Han, Chuan-Hsiang	Proceedings of the ACM Symposium on Applied Computing	2022	Examines the effect of volatility on token valuation.
Herding and anchoring in cryptocurrency markets: Investor reaction to fear and uncertainty	Gurdgiev, Constantin and O'Loughlin, Daniel	Journal of Behavioral and Experimental Finance	2020	Investigates the correlation between investor perception, sentiment, and cryptocurrency value, focusing on "anchoring" and "compliance."
Network Dynamics of a Financial Ecosystem	Somin, Shahar and Altshuler, Yaniv and Gordon, Goren and Pentland, Alex 'Sandy' and Shmueli, Erez	Scientific Reports	2023	Applies theoretical concepts to BTC and ETH, drawing comparisons to real-world networks.
The Ecological System of Digital Asset Markets: Based on the Perspective of Asset Trading and Valuation	Chi, Cheng and Chen, Wenqu and Liu, Hang and Li, Xiaozhuang and Meng, Fuyu	2023 IEEE International Conference on Engineering, Technology and Innovation	2023	Incorporates the Network Value to Transactions (NVT) ratio in analysis to evaluate the relationship between transaction volumes and the market value of cryptocurrencies.
A Time-series Analysis of How Google Trends Searches Affect Cryptocurrency Prices for Decentralized Finance and Non-Fungible Tokens	Kaneko, Yuta	2021 International Conference on Data Mining Workshops	2021	Examines the impact of Google Trends searches on cryptocurrency prices, highlighting the influence of public interest and search behavior on market dynamics.

Title	Author	Journal	Year	Comment
The token's secret: the two-faced financial incentive of the token economy	Drasch, Benedict and Fridgen, Gilbert and Manner-Romberg, Tobias and Nolting, Fenja and Radszuwill, Sven	Electronic Markets	2020	Discusses the 'chicken and egg' dilemma in the cryptocurrency market.
What drives DeFi prices? Investigating the effects of investor attention	Shaen Corbet and John W. Goodell and Samet Günay	Finance Research Letters	2023	Emphasizes the connection between DeFi tokens and cryptocurrencies during downturns, examining the investor perspective and how investor interest serves as a key driver of value.
Digital Asset Valuation	Wulf A. Kaal, Samuel Evans and Hayley Howe	SSRN Electronic Journal	2022	Acknowledges that traditional valuation methods are partially suited for digital assets, emphasizing the need for tailored approaches.
Token Valuation Methods	Keegan Selby	Medium	2018	Delves into the use of the NVT (Network Value to Transaction) metric to evaluate network value against transaction volume (grey literature).
Using NVT and NVTG in practice to value the most popular cryptocurrencies	Vikram Arun	Medium	2019	Proposes a new form of NVT to level out the volume of transactions over a longer period, offering a stable metric for analyzing market dynamics (grey literature).
Cryptoasset Valuations	Chris Burniske	Medium	2017	Analyzes valuation methodologies like DCF and the Equation of Exchange, applying them to cryptocurrencies to assess their effectiveness (grey literature).
Token valuation: The misunderstood importance of token economics	Jose Maria Macedo	Medium	2018	Focuses on the concept of value creation and capture by a token, examining how these dynamics play out in the cryptocurrency market (grey literature).

Table 4.1: Summary of Research Papers on DeFi and Cryptoasset Valuation

4.2. Valuation Cryptocurrencies

The valuation of cryptocurrencies has developed more than that of DeFi tokens, reflecting greater interest from investors, financial advisors and the scientific literature. The increased interest can likely be attributed to the higher level of popularity and wider adoption of cryptocurrencies in comparison to DeFi tokens. Bitcoin and Ethereum, two prominent cryptocurrencies, have gained significant recognition and are extensively utilised and acknowledged throughout multiple industries, serving as both a payment method and an investment instrument.

Research in this domain frequently depends on conventional monetary theory, given that cryptocurrencies like Bitcoin are progressively assuming the role of a recognised and prevalent type of currency. These valuation models could potentially be applied to DeFi tokens as well. However, given that cryptocurrencies are more similar to traditional currencies in their nature and function, the preference is to use these models specifically for cryptocurrencies.

Metrics such as market capitalisation, liquidity, volatility and user adoption are commonly used to evaluate cryptocurrencies. Market capitalisation quantifies the overall worth of a cryptocurrency by calculating the product of the present price and the total quantity of coins in circulation. Liquidity refers to the ease with which an asset can be converted into currency without significantly affecting its market price. Volatility quantifies the degree of fluctuation in the price of an asset during a specific timeframe, and serves as an essential indicator for assessing the stability of a cryptocurrency as a store of value.

The Price-to-Earnings (PE) ratio is a commonly employed basic indicator utilised by financial experts to assess the value of a firm. The ratio enables investors to assess the relative worth of a firm by comparing its share price to its earnings per share. However, significant challenges arise when attempting to apply this indicator to the cryptocurrency space. In the context of cryptocurrencies, 'profits' refer to the accumulation of transaction fees and block rewards. These fees are earned by the individuals responsible for block creation, namely miners, rather than by token holders. Hence, employing the P/E ratio to provide a comprehensive assessment of a cryptocurrency's value is misleading and unsuitable. For example, in the case of Bitcoin, the PE ratio does not accurately reflect the value to its holders because it does not take into account the gains made by miners.

In order to overcome these constraints, unique metrics have been devised specifically tailored to the the digital currency domain. One such metric is the NVT ratio. The ratio is calculated by dividing the market value of the cryptocurrency by its transaction volume in USD within the past 24 hours. The NVT ratio quantifies the intrinsic worth of a token by evaluating its usage frequency in transactions, hence indicating its role as a medium of exchange. A high NVT may indicate that the token is overpriced in relation to its usage in transactions, whilst a low NVT may imply that the token is undervalued. The paper by Chi et al. (2023) used the NVT indicator to examine the worth of cryptocurrencies, illustrating how this ratio might offer a more precise assessment of their usefulness and inherent value.

Another novel metric is the Price-to-Metcalfe's (PM) ratio, derived from Metcalfe's law. During the 1980s, Robert Metcalfe, the creator of Ethernet, suggested that the worth of a network was directly related to the square of its active user count. When it comes to cryptocurrencies, the PM ratio evaluates the worth of a coin based on the quantity of people actively participating in the network. Nevertheless, this technique has certain constraints, as it fails to take into account inactive users who are accumulating cryptocurrency for the purpose of saving their wealth. However, the PM report can offer valuable insights into the potential for adoption and development of a cryptocurrency, providing an additional viewpoint for evaluating its value.

These new reports enable investors and analysts to more effectively assess cryptocurrencies, taking into account their transactional usefulness and network potential, so enhancing their comprehension of their value. Nevertheless, the precise factors that affect the expected value of a token have not been definitively established. In classical finance, multiples are calculated by dividing a 'fundamental' such as earnings or book value by a market component like share price. These multiples serve as a metric for assessing the relative worth of a company in relation to its competitors. However, in the realm of cryptocurrencies, there is no inherent worth that can be compared to the book value that exists in regular equities. This complicates the process of creating comparable value indicators.

The study by Liebi (2022) introduced a metric that acts as a substitute for cryptocurrency fundamentals: the average number of active addresses over a period of 30 days. This indicator is derived from the mean number of distinct active addresses, also known as wallets, that engage in on-chain transactions throughout a 30-day timeframe. In order to compute this measure, data can be obtained regarding the quantity of distinct addresses documented in transactions on the blockchain within the specified time frame. Subsequently, the addresses-to-network value statistic is derived by dividing the total number of active addresses by the market capitalisation of the cryptocurrency. Studies indicate a direct relationship between this measurement and the profitability obtained from the cryptocurrency. Essentially, a greater quantity of active addresses correlates with a rise in the cryptocurrency's worth, indicating that the level of activity on the blockchain network directly influences the token's price. The paper's author argued that these findings can be explained by asserting that, over time, the worth and cost of cryptocurrency assets are more strongly linked to the underlying parameters of the blockchain rather than mere speculation.

Simultaneously, the study made by Liu and Zhang (2023) presented a novel metric for evaluating the price of Bitcoin in relation to its utility. The statistic known as token utility seeks to encompass and consider all the essential attributes of cryptocurrencies. The notion of token utility is founded on the idea that the worth of a cryptocurrency should encompass not just speculative transactions, but also its intrinsic usefulness, such as its capacity to enable transactions, smart contracts and other practical applications inside the blockchain network. The token utility measure aims to provide a thorough and all-encompassing assessment of the worth of a cryptocurrency. It considers essential criteria including network security, scalability and user adoption.

These studies emphasised the significance of creating new metrics that can more effectively represent the unique characteristics of the cryptocurrency market in comparison to conventional financial methodologies. The addresses-to-network value metric and the token utility idea are notable efforts to overcome the current disparity in cryptocurrency valuation. These concepts offer investors and analysts more suitable methods to assess the value of these digital assets. While speculation remains significant in influencing short-term cryptocurrency pricing, these emerging indicators indicate that the long-term worth of cryptocurrencies is heavily impacted by their fundamental features and the utility of their blockchain network. By utilising measurements such as the average number of active addresses and token utility, researchers can gain a deeper understanding and quantify the distinct features of cryptocurrencies. This enables us to evaluate these assets more precisely and meaningfully, capturing their genuine inherent worth and long-term growth potential.

$$\text{Token utility} = \frac{\text{token velocity} \times \text{staking ratio}}{\text{price volatility} \times \text{dilute rate}}$$

The price-utility ratio (PU ratio) has demonstrated superior long-term forecasting capability compared to other techniques.

Chen et al. (2020) showed that increased user adoption and token price stability are linked to reduced volatility, as one might expect. Increased pricing stability is commonly indicative of a mature market and a well-established user base that is less susceptible to speculative fluctuations.

Gaining a comprehensive understanding of the volatility related to the world of cryptocurrencies is crucial for accurately identifying indicators used to determine their value. Ethereum, a complicated system that serves as both a cryptocurrency and a platform for smart contracts and decentralised apps, experiences a substantial growth in its complexity and internal volatility. Each time a new project is derived from these platforms, it introduces a variable that contributes to the current value of the underlying platform. Every novel undertaking has the potential to introduce originality and increased worth, but it also entails potential hazards and unpredictability.

A study undertaken by Somin et al. (2020) contended that the Ethereum ecosystem, despite its diverse content, volumes and structure, exhibits similar behaviour to many real-world networks. From an ordinary viewpoint, the Ethereum ecosystem is perceived as a highly unpredictable and unstable market. By applying network theories, patterns of stability and equilibrium become apparent. This indicates the existence of a tendency towards a consistent network, rather than a platform influenced by different external and internal factors. The Ethereum network, despite its intricate nature, may exhibit resilience characteristics similar to those discovered in other forms of networks, such as social or infrastructural networks. Additional research is needed to verify the accuracy and strength of this study, but it does offer a constructive method for comprehending the fundamental factors contributing to volatility and instability. Utilising network models to examine platforms like Ethereum can offer novel perspectives on effectively managing and forecasting volatility, consequently enhancing investment strategies and regulatory determinations. Moreover, the capacity to discover stability patterns within these networks can assist in detecting early indications of speculative bubbles or imminent crises, providing more advanced instruments for risk management.

Many of the valuation metrics proposed can only be applied to certain types of cryptocurrencies and tokens. This is particularly true for models that rely on parameters such as Price-to-Earnings ratios or Token Utility, which require specific data related to the profits generated by the tokens themselves. These profits are often tied to services like mining or staking, where the tokens serve a functional role in generating revenue. However, not all tokens are designed with these mechanisms in mind. Many tokens are created for purposes beyond profit generation, such as governance or utility within a specific ecosystem. Therefore, while these valuation models are useful, their applicability is limited to tokens and cryptocurrencies with revenue-generating mechanisms, highlighting the need for more tailored approaches for other types of tokens.

4.3. Valuation DeFi Tokens

The study conducted by Şoiman et al. (2023), which examined a collection of DeFi tokens with a market capitalisation over $1 billion, determines that multiple factors impact the token market. One significant factor is the association with prominent cryptocurrencies like Bitcoin and Ethereum. These two cryptocurrencies are strongly correlated with the whole blockchain market, which is expected due to their significant influence and importance in the cryptocurrency industry. These cryptocurrencies serve as an indicator for the overall ecosystem, exerting a substantial impact on market dynamics. The linkage between DeFi tokens and cryptocurrencies is confirmed by Corbet et al. (2022), which emphasised that this connection is particularly noticeable during bad markets, when there is an increase in volatility and investor attention. Consistently, the main factor that consistently affects DeFi token values is the correlation with investor interest, which has been identified as the primary driver for the price movement of DeFi tokens. Corbet et al. (2022) also discussed the network effect, which is a crucial factor in the competitive environment of DeFi. The 'chicken and egg' dilemma is a detrimental aspect that impacts initiatives throughout their first phases. This issue arises when the initial user base is insufficient, leading to a decrease in the appeal of the platform for potential new users. This creates a vicious circle that is challenging to overcome. As the user base of a DeFi token expands, its value and utility progressively rise, ultimately resolving the 'chicken and the egg' predicament.

The level of interest from investors, assessed using a variety of different indicators such as online search volume, social media mentions and web traffic, has been identified as a factor influencing the pricing of DeFi tokens. The data indicates that when investors concentrate their attention on a specific token or project, prices have a tendency to increase, independent of the basic factors supporting them. This event demonstrates the pivotal significance of market sentiment and speculation in the realm of cryptocurrencies and DeFi tokens. These characteristics, when combined with previous one, provide a more thorough comprehension of the forces driving the DeFi token market. This highlights the significance of taking into account both conventional economic reasons and behavioural and societal dynamics.

Examining the concept of the 'chicken and egg' dilemma, the research by Drasch et al. (2020) investigated how blockchain-based tokens can address this issue during the initial phase of platforms. Nevertheless, the assessment of these tokens has dual implications: firstly, they serve as a motivation for the initial expansion of the platform; secondly, they may limit the utilisation of the platform after its debut. Blockchain-based tokens, namely utility tokens, provide a monetary motivation for users to promptly join the network, with the promise of a rise in token worth as the platform expands. The researchers have constructed a model to analyse the worth of tokens and the incentives that come with them. According to their findings, utility tokens have the potential to solve the 'chicken-and-egg' dilemma. During the platform's early stage, tokens are sold at an initial price, and the funds generated from the sale are utilised to finance the platform's development. Potential buyers of the tokens are motivated to purchase them early due to the promise of a subsequent rise in value. This phenomenon results in a self-fulfilling prophecy: when a sufficient number of individuals have trust in the future profitability of the platform, the tokens' worth will rise, hence attracting more users and investments. However, after the network is established and functioning, the tokens' value as a form of payment can have a contradictory impact. Users who anticipate a sustained gain in token value may be motivated to retain them instead of utilising them for platform transactions.This may reduce the network's practical usage if users decide to hold tokens as investments rather than spending them. The study made by Şoiman et al. (2023) demonstrated that the expansion of transactions and addresses has a negative effect on the returns of DeFi tokens, namely in terms of exchange frequency and token volatility. The occurrence can be elucidated by the existence of significant volatility and the emergence of substantial financial bubbles in the DeFi market. The rapid increase in transactions and active addresses mostly indicates a rise in speculative activity rather than a long-term and practical utilisation of the technology.

The assessment of DeFi tokens and cryptocurrencies is hindered by the frequency of trading and the level of volatility. However, the utilisation of network theories presents novel viewpoints and tools to comprehend and handle these intricate dynamics. The study made by Şoiman et al. (2023) presented a statistic designed specifically for the DeFi market, which is calculated by dividing the Total Value Locked by the market capitalisation.

The TVL is a key measure of a DeFi platform's success, representing the combined intrinsic and allocated value within the platform. TVL denotes the quantity of funds that are securely held within smart contracts and can be seen as a measure of the level of confidence users have in the platform. A large TVL indicates a substantial number of people actively utilising and investing in the platform, hence enhancing its legitimacy and total worth.

Utilising ratios to gain insights is a well-established method in conventional finance. However, in the context of DeFi, as highlighted by Şoiman et al. (2023), these ratios are still in the early stages of development and require more fine-tuning. The findings derived from this initial analysis do not yield definitive conclusions on a potential correlation with DeFi token returns, highlighting the necessity for additional research and analysis to enhance comprehension of these associations and their relevance within the DeFi domain.

The paper authorized by Metelski and Sobieraj (2022) made a noteworthy contribution to the analysis of measures that may be utilised to evaluate tokens. This study examined various essential parameters to facilitate the comparison of DeFi protocols based on their analytical performance. Among the other measures examined, alongside TVL, the significance of Gross Merchandise Volume (GMV) becomes apparent. GMV indicates the whole value of sales. This statistic is extensively utilised in the examination of Internet enterprises, specifically e-commerce platforms, and serves as a crucial indicator of the economic efficacy of DeFi protocols. It is crucial to emphasise that every variable utilised in the study by Metelski and Sobieraj (2022) directly affected the assessment of DeFi tokens. TVL, total revenue and GMV typically have a favourable influence, signifying increased liquidity, popularity and usage of the protocols. However, it is important to note that protocol revenue and inflation component could potentially have a negative impact, indicating possible inefficiencies or expenses related to the upkeep of the protocol. According to the study, TVL is identified as the most significant factor for this market. It is closely followed by transaction volume, which serves as an indicator of investor attentiveness, and network effects. A larger TVL in DeFi protocols signifies increased liquidity, popularity and usability. This suggests that users are prepared to allocate substantial resources to the platform, indicating a high level of confidence and potential for growth.

This conclusion aligns with the results presented in the paper by Şoiman et al. (2023), which emphasised that TVL serves as a crucial metric for evaluating the effectiveness and worth of DeFi protocols. Examining measures such as GMV and TVL offers a more thorough comprehension of the aspects that impact the DeFi market. This analysis aids in identifying the crucial elements that contribute to the value and performance of tokens. Nevertheless, the investigation revealed that the assessment of DeFi tokens is intricate and necessitates a complex methodology that takes into account many economic, operational and market factors.

Ultimately, while ratios like TVL-to-market cap are still being refined inside the DeFi framework, conventional measures tailored to the unique characteristics of the DeFi market, such as TVL and GMV, offer valuable perspectives on the worth and effectiveness of tokens. Further investigation in this field is crucial for the development of more resilient and precise models that more accurately depict the nature of these new digital assets.

The research made by Metelski and Sobieraj (2022) highlighted the absence of extensive studies in the current literature that employ rigorous econometric analysis to sufficiently explain the valuation of DeFi protocols using particular financial measures. The existence of this gap emphasises the necessity of creating more advanced valuation models that are specifically tailored to the unique characteristics of digital assets. The analysis undertaken by Kaal et al. (2022) also recognized that traditional valuation methods are only partially suited for digital assets. Different valuation models for digital assets exhibit substantial variation, and the absence of standardisation creates ambiguity and perplexity among investors and managers, so impeding the ability to make well-informed decisions. An enduring theme in the world of the digital currency is that of speculation. Indeed, according to a study conducted by Pakhnenko et al. (2022), the primary elements that affect the value of tokens are transaction volume, use as a medium of exchange, mining costs and speculation. Among these factors, speculation is the most crucial element that tends to have the greatest influence on the token market. Investments in this involves a greater financial risk for users compared to typical financial instruments. Speculation can lead to swift price fluctuations, rendering it challenging to forecast the future worth of tokens and amplifying market volatility.

For example, considering cryptocurrencies obtainable through the mining process, such as Bitcoin, the cost of mining is a determining factor. This procedure operates independently of a central bank's management or regulation and instead relies on the computational power of the equipment being utilised. The volatility of energy prices, advancements in mining hardware technology and the computational complexity significantly impact the mining costs, thus influencing the value of the cryptocurrency. The dependence on technical and operational variables adds more intricacy to the assessment of these assets. Overall, the absence of established criteria for determining the value of digital assets and the widespread practice of engaging in speculative activities present considerable obstacles for both investors and management. Traditional valuation approaches are inadequate for comprehending the intricacy and instability of the cryptocurrency and DeFi token market. Therefore, it is crucial to develop new approaches that account for the unique characteristics of digital assets, integrating factors such as speculation, mining costs and transactional use to provide a more accurate and reliable valuation. Future research should focus on these aspects to address existing gaps and improve the understanding and management of digital asset value

4.4. Investor Bias and Behavioural Finance

When evaluating cryptocurrencies, it is important to also take into account investor bias and behavioural finance. The effective determination of the value of cryptocurrencies is significantly hampered by the dynamic nature of cryptocurrencies combined with investor behaviour and sentiment. Behavioural biases in trading and investing greatly increase risks, reducing market predictability and stability. It is challenging to identify macro trends that may be used to predict events that are helpful in determining valuations. This is because many of the outcomes may not be caused by traditional economic patterns, but rather by behavioural factors.

The report by Gurdgiev and O'Loughlin (2020) investigated the correlation between investor perception, sentiment and the value of cryptocurrency. Specifically, the analysis focused on "anchoring" and "compliance" biases. Investor sentiment has been found to have a substantial impact on the price of cryptocurrencies, indicating that they can serve as a means to hedge against uncertainties in the stock market. Compliance bias is demonstrated by the correlation between investor optimism and price increases. When taking a broad view and examining all financial markets, it is noticed that generally positive or negative sentiment has an asymmetric effect on the price of cryptocurrencies. In this context, anchor biases, when present, do not follow a linear trend.

Emerging fields of research, such as behavioural finance, sentiment analysis and cryptocurrencies, are consistently generating information that supports broader topics. The valuation of cryptocurrencies is heavily influenced by public opinion and collective mood, which have a considerable impact on their price movements. Google Trends searches and social media activity are significant indicators of market sentiment towards various cryptocurrencies, making them indispensable tools for precise analysis and prediction.

This study made by Kaneko (2021) examined the impact of Google Trends searches on cryptocurrency prices by analysing the temporal patterns of weekly price variations in Bitcoin, Ethereum, and a group of DeFi altcoins that have the highest market capitalisation in the DeFi sectors. Altcoins [1] are all cryptocurrencies other than Bitcoin. They are often launched to meet specific needs that Bitcoin cannot address or to offer additional functionality. For example, some altcoins were created to support certain dApps, while others were developed to improve Bitcoin's scalability. Google Trends searches were utilised as an explanatory factor for the weekly changes in prices. The results showed that the price of Bitcoin positively influences the prices of Ethereum and many DeFi altcoins. However, Google Trends searches related to specific brands and the general market had a negative impact on most of the analysed cryptocurrencies.

Specifically, for certain altcoins like LUNA and MKR, conducting searches that are related to the brand and market has proven to be a reliable method for predicting long-term price movements.

Essentially, comprehending the impact of behavioural bias and investor emotion is crucial for a precise assessment of cryptocurrencies. Google Trends searches and social media sentiment analysis provide significant tools for monitoring and forecasting price swings. Nevertheless, due to the intricate nature and instability of the cryptocurrency market, it is imperative to persistently improve these procedures in order to enhance the precision of valuations and mitigate the dangers linked to investing in these digital assets.

Ultimately, although the assessment of cryptocurrencies and DeFi tokens is currently in its initial and dynamic phase, the advancements achieved so far offer a hopeful founda-

[1] https://coinmarketcap.com/academy/glossary/altcoin

tion for future investigation and advancement. Currently, the cryptocurrency industry is marked by significant intricacy and instability, driven by a combination of economic, technological, and behavioural elements. Conventional valuation methods are only partially suitable for these digital assets, necessitating the incorporation of new criteria and inventive approaches. The growing comprehension of value drivers, such as TVL, GMV, and the impact of investor sentiment, provides essential tools for more accurately assessing the worth of these assets. Moreover, the incorporation of innovative methods, such as analysing social media sentiment and utilising state-space models, can greatly enhance the precision of values.

Further investigation into the field of behavioural finance and econometric study of cryptocurrencies is crucial in order to create stronger and more dependable valuation models. These models should have the capability to not only comprehend economic fundamentals but also the behavioural variables that impact the cryptocyrrency market.

With the advancement of blockchain technologies and the establishment of standardised valuation standards, it will become feasible to attain a more precise and dependable valuation of these digital assets. Implementing this measure will contribute to the stabilisation of the market, thereby mitigating the fluctuations and hazards linked to investments in cryptocurrencies and DeFi tokens. Consequently, enhancing comprehension and control over the worth of cryptocurrencies will not only offer increased protection for investors, but also encourage the acceptance and enduring utilisation of these revolutionary technologies, thereby facilitating the growth of a stronger and more durable decentralised financial system.

4.5. Valuation in Grey Literature

The research work involved several articles published on major forums such as Medium[2]. The in-depth studies carried out covered various branches of valuation, in particular the creation of guidelines and spreadsheets and the in-depth study of various multiples.

One aspect that has emerged from these forums is a much more focused approach to looking more specifically at the details of the individual project and what aspects need to be considered. This mode is much more focused on understanding the individual use case. A detailed understanding of the Tokenomic model, developments and applications is often encouraged. Thus, there is a shift from a broad, generalist approach that categorizes tokens into macro-groups for standardization, towards a more meticulous and detailed

[2]https://medium.com/

methodology. Indeed, it is worth remembering that these articles are often produced with the aim of being investment thesis, thus potentially to derive investment advice. Several articles, in fact, thoroughly assessed the crypto project from every point of view. They have given considerable imoportance to the analysis of the team, the developers and their network, identified as a possible driver that can affect the value of the token.

Before focusing on the grey literature valuation articles, it is interesting to clarify a concept that is sometimes not adequately considered. Jose Maria Macedo's research work in Medium (Macedo, 2018) highlighted the often misunderstood importance of tokenomics in token valuation. Differentiating between value created and value captured by a token is crucial to understanding its valuation. For example, a project may generate enormous value through its protocol, but only a small part of this value can be captured by the token itself.

Equity represents legal property in a company and its valuation can be traced back to the company's future cash flows. In contrast, tokens do not confer any legal ownership. They are mainly used as currency to pay for services within an underlying protocol. This makes their valuation more complex, as it depends not only on the demand for the protocol, but also on the degree of correlation between the demand for the protocol and the demand for the token itself.

To evaluate a token, it is necessary to consider the demand and supply of the underlying protocol. If tokens functioned like equity, guaranteeing legal ownership of a company capable of generating cash flow, valuation would be easier. However, since tokens do not represent property and are used as an exchange currency, the economic model of the token must also be considered. This involves analysing the demand for the token.

Example 1: Ripple Ripple Labs created the Ripple Network blockchain-based protocol and XRP token. The aim of the project is to replace the SWIFT protocol for international banking transactions. Although the target market is huge ($5 trillion per day), the demand for XRP is not directly related to the demand for the Ripple protocol. XRP does not represent an ownership stake in Ripple Labs, and its demand is limited to specific functions such as 'bridge currency' for banks, payment of transaction fees (which are insignificant in terms of volume) and a small reserve for addresses using the network.

Example 2: Coinseed Coinseed allows users to make micro-investments in cryptocurrencies by automatically rounding up credit card purchases. Coinseed's CSD token is used to get 50 per cent of the revenue from the portfolio replication function, thus not tying the value of the token to the overall success of the platform, but to a specific function.

Equity and tokens compete for the value created by a company or protocol. A company with valuable equity will necessarily have less valuable tokens and vice versa. For example, Ripple Labs generates revenue with fees to banks, capturing little value with XRP. In contrast, the Ethereum Foundation holds only 1% of ETH in circulation and generates no cash flow, causing all value to be captured by ETH tokens. A company can transfer value between equity and tokens by charging for services in fiat and using the earnings to buy and burn tokens, increasing the price of the token. Alternatively, it can charge in native tokens, sell the tokens in the market and distribute the gains to shareholders as dividends, reducing the value of the token by increasing the supply.

Therefore, the valuation of tokens requires a thorough understanding of the underlying economic models and the supply and demand dynamics specific to each protocol. This detailed approach helps identify the unique characteristics and potential of each project, providing a more accurate and comprehensive evaluation.

As already mentioned in the previous section, to value cryptocurrencies, an innovative method introduced by Willy Woo and Chris Burniske in 2017 was the NVT ratio, which adapts the traditional P/E ratio by using transaction volume as a proxy for cryptocurrency profits. Cryptocurrencies that can be valued with this method are for example Bitcoin, whose main function is as a means of payment and store of value. For DeFi projects, however, where fee structures may vary, the NVF (Network Value to Fee Revenue) ratio is used, which uses fee income as a denominator, allowing for a uniform comparison between different projects. For example, Ethereum generates revenue through gas fees, commissions paid in ETH as a reward to miners or validators to execute transactions.

In the article written by Selby (2020) it is suggested that, in order to achieve an effective comparison of investment options using relative ratios such as NVT or NVF, a calculation with median values for each category is used, establishing a baseline to identify potential under- or over-valuations. Extremely high ratios may indicate overvaluation, highlighting a competitive discrepancy between the current value of the network and the ability of its tokenomics model to generate fees, compared to similar protocols.

However, there are challenges in applying these ratios. Network effects resulting from the limited availability of fiat on-ramps (exchange platforms that allow the conversion of traditional currency into cryptocurrency, such as USD into ETH) can affect investment allocation. This phenomenon, known as the 'Coinbase Effect,' can give a significant competitive advantage to projects that first make these conversions possible (ex. 0x), further complicating the comparative analysis between different cryptocurrencies and DeFi protocols.

Recently, a new metric called Network Value to Transactions/Growth (NVTG) was proposed, which serves as the equivalent of the Price-Earnings/Growth (PEG) ratio for fast-growing, future-oriented markets. A lower value of NVT and NVTG indicates a 'better deal' for the value received.

Arun (2018) proposed a new form of NVT to level out the volume of transactions over a longer period, eliminating irregularities and noise that can distract from the fundamental, long-term value of the network. Kalichkin's version of the NVT is a great way to turn a fundamental metric into a dynamic trading signal.

Proposed changes to the NVT include changing the moving average from simple to exponential for greater responsiveness to market changes, and also using on-chain volume to exclude long transaction chains to achieve a cleaner and more accurate measure of actual transactions. These improvements aim to provide a more accurate and useful valuation of cryptocurrencies, better reflecting their intrinsic value and market dynamics.

Analysing the grey material, it was found that a frequently used and popular valuation method is the 'Equation of Exchange'. This equation, widespread in monetary and macroeconomic theory, has been adapted to be used for the valuation of certain types of cryptocurrencies. In particular for currency tokens that aims to fulfil one or more of the three primary roles of currency, namely a medium of exchange, a unit of account, and a store of value.

Equation of exchange:

$$M \cdot V = P \cdot Q$$

- M = size of the asset base, monetary base
- V = velocity of the asset each crypto changed hands tot times
- P = price of the digital resource being provisioned by cryptonetwork
- Q = quantity of the digital resource being provisioned

Burniske (2017), one of the forerunners of the use of such a formula, hypothesised the application of such a formula to tokens that were intended to enter a market of physical assets already present. For example, assuming one wanted to estimate the token value of a project such as Filecoin, set up to offer a decentralised storage service, in which staking rewards are paid to users who provide GB of storage, there would be some adjustments to the formula to be implemented:

1. Use M as average in the year due to inflationary nature of crypto;

2. P does not represent the price of the cryptoasset, but instead the price of the resource being provisioned by the cryptonetwork, e.g. $/GB;
3. Q refers to the underlying resource and not the number of tokens.

If the projects did not start out with the aim of proposing a service with an underlying asset, there is evidence of some papers using P and Q with a greater focus on the papers.

There are several applications of this formula:

- Used to derive the Current Utility Value.

$$\text{CUV}_t = \frac{M_t}{\text{Number of tokens in float}_t}$$

- Knowing M, i.e. the size of the token asset base, one can derive the utility of the individual token by knowing the supply;
- P*Q = GDP of the taken cryptocurrency economy
- The GDP of a crypto network is represented by the on-chain transaction volume of its crypto asset. On-chain transaction volume could represent a crypto's GDP, but it's imperfect because often 30% of that is related to transactions of the asset between exchanges (This is not an exchange of value but speculation).
- Taking into consideration a particular year, in which we already know M, P and Q, it's possible to derive V and make comparisons.

Chris Burniske in his article provided important food for thought that has not yet been dealt with up to this point. Relating a longitudinal analysis of the token, having analysed tokenomics and having derived future utility values over the years with the Equation of Exchange, it is possible to construct a DCF to calculate the discounted price of the token. Although the DCF is the most commonly used model in classical finance, it is particularly complex to transpose to crypto. The only cases in which it can be implemented are cryptocurrencies where the value can be derived with the equation of exchange, or those tokens that pay dividends or premiums over time. However, it remains extremely complex to estimate an effective discount factor. The high volatility of the cryptocurrency world does not allow for a predictable discount factor calculation in both the short and long term. Although the grey material collected does not allow for comprehensive conclusions regarding an established and widespread valuation methodology, it is important to specify the recentness of the topics discussed.

4.6. Concluding Remarks and Next Steps

The findings from the literature review, as well as the review of grey literature, reveal a distinct divergence in the approaches used for valuing cryptocurrencies and DeFi tokens. Both academic and grey literature are heavily focused on valuation methods tailored to cryptocurrencies, often overlooking DeFi tokens. Many valuation models for cryptocurrencies focus on metrics related to revenue generation, such as Price-to-Earnings ratios or Token Utility, which require data on profits from activities like mining or staking. These models are particularly relevant for cryptocurrencies designed to generate fees or other financial returns. In contrast, DeFi tokens, which often serve governance or utility purposes within decentralized ecosystems, present a unique challenge and opportunity for valuation.

Given the lack of structured models, it was decided to propose a relative valuation model to address the existing gap. Some of the insights gathered from both academic and grey literature will be adapted to conduct a relative valuation through empirical tests.

The DeFi token landscape, in particular, stands out as a promising area for relative valuation analysis, where different tokens can be compared based on their utility within decentralized financial systems. Meanwhile, valuation models for cryptocurrencies tend to be more focused on metrics related to fee generation and other revenue mechanisms. This differentiation highlights the need for tailored approaches to valuation depending on the token's functional role and underlying ecosystem.

In the upcoming chapters, this valuation proposal will be applied to two specific categories of projects: Layer 2 solutions and Decentralized Exchanges. The objecting will be to provide a deeper understanding of how valuation models can be applied to different aspects of the DLT and DeFi ecosystems.

5 | L2 Analysis

This chapter introduces the steps that lead to the valuation of Layer 2 projects, starting with a detailed exploration of the relevant academic literature. The initial section focuses on a literature review that is crucial for establishing a comprehensive understanding of the various types and directions of scientific discourse surrounding L2 solutions. This review serves not only to map out the key trends and insights in the field but also to extract the distinctive characteristics of L2 systems. These characteristics will form the basis for identifying potential parameters on which to anchor a relative valuation of these technologies.

The second part of the chapter moves to a deeper analysis of why specific valuation parameters have been chosen. These parameters, derived from the literature review, are examined in depth, with particular attention paid to their relevance and applicability to L2 systems. The rationale for their selection is based on how these characteristics impact scalability, efficiency and adoption, which are core to the value proposition of L2 solutions.

Finally, the chapter sets the stage for Chapter 7, where these selected parameters will be put to the test through empirical analysis. This final step will involve performing a relative valuation to compare L2 projects based on real-world data, offering insights into their competitive positioning and future potential within the decentralized technology landscape.

5.1. Paper Review

The table 5.1 contains a collection of the papers that have been used to conduct the literature review. The process that led to the selection of these papers is thoroughly discussed in the methodology section (Paragraph 2.1.3) and visually outlined in the PRISMA diagram (Figure 2.3). This approach ensures a structured and transparent selection process, offering a comprehensive overview of the research landscape relevant to the study.

This collection of studies provides a broad and insightful analysis of the current state of blockchain technology, with a particular focus on the scalability challenges faced by Layer

1 networks and the potential solutions offered by Layer 2 systems. A common theme is the difficulty that Layer 1 blockchains, like Ethereum and Bitcoin, experience in handling large volumes of transactions efficiently due to limitations in processing speed and high transaction fees. These challenges have driven the development of Layer 2 solutions, which aim to improve scalability by increasing transaction throughput and reducing costs, thus enabling blockchains to better support growing user demands.

Additionally, the studies highlight the importance of security and the need to address vulnerabilities inherent in blockchain systems, such as the risk of cyber-attacks, including double-spending. As Layer 2 technologies evolve, they not only offer scalability solutions but also contribute to strengthening the security framework of blockchain ecosystems.

Another important area of discussion is the "Blockchain Trilemma", which refers to the difficult balance between scalability, security, and decentralization. While Layer 2 solutions provide scalability improvements, there is an ongoing challenge in optimizing all three aspects simultaneously.

Overall, these analyses emphasize the growing importance of Layer 2 technologies in improving the performance and usability of blockchain networks. However, they also acknowledge the practical limitations and challenges that still exist, particularly in how these solutions interact with Layer 1 systems and in ensuring the security and stability of decentralized networks.

Summary of Research Papers on Blockchain Scaling and Layer-2 Solutions

Title	Author	Journal	Year	Comment
Scalability of blockchain: a comprehensive review and future research direction	Rao Iqra Sadia, Kiah Miss Laiha Mat, Hameed M. Muzaffar, Memon Zain Anwer	Cluster Computing	2024	Addresses scalability issues in Layer-1 solutions like Ethereum and Bitcoin. Proposes Layer-2 solutions to increase transaction speed and reduce fee costs.
Layer 2 Blockchain Scaling: a Survey	Sguanci Cosimo, Spatafora Roberto, Vergani Andrea Mario	ArXiv	2021	Analyzes Layer-2 solutions in the blockchain landscape. Highlights throughput limitations and contrasts Bitcoin with traditional payment systems like Visa.
Profitable double-spending attacks	Jang Jehyuk, Lee, Heung-No	Applied Sciences (Switzerland)	2020	Explores double-spending attacks, a key risk in blockchain technology. Investigates how these attacks succeed and the protective measures needed to safeguard the network.

Title	Author	Journal	Year	Comment
The Blockchain Trilemma: an Evaluation Framework	Quattrocchi Giovanni, Scaramuzza Filippo, Tamburri Damian A.	IEEE Software	2024	Examines the three core parameters of the blockchain trilemma: scalability, security, and decentralization, explaining why simultaneous optimization of all three is unattainable.
Practical Limitations of Ethereum's Layer-2	Ray Neiheiser, Gustavo Inácio, Luciana Rech, Carlos Montez, Miguel Matos, Luís Rodrigues	IEEE Access	2024	Focuses on Layer-1 network issues, using Ethereum as a case study. Analyzes how Layer-2 solutions can partially mitigate these problems and examines their interaction with the main chain.
Blockchain Beyond Bitcoin: Block Maturity Level Consensus Protocol	Muniba Memon, Umair Ahmed Bajwa, Asad Ikhlas, Yusar Memon, Sanaullah Memon, Mukesh Malani	-	2018	Introduces the concept of hard fork without focusing on Layer-2 solutions, a topic covered in another chapter.
A survey of Layer-two blockchain protocols	Ankit Gangwal, Haripriya Ravali Gangavalli, Apoorva Thirupathi	Journal of Network and Computer Applications	2023	Provides a detailed overview of current Layer-2 technologies. Emphasizes Layer-1's role in ensuring security and Layer-2's role in handling transactions and sending them to the main chain.

Table 5.1: Summary of Research

5.2. Challenges of L2

Upon comprehensive examination in the introduction chapter, the potential and innovation offered by Blockchain technology can be discerned to mostly consist of three primary qualities:

- Decentralization
- Security
- Scalability

As extensively discussed in the paper by Rao et al. (2024) and in the paper by Quattrocchi et al. (2024), the trilemma arised from the concept that it is not possible to maximize all three attributes simultaneously, but it is possible to reach an equilibrium and succeed in doing so. Decentralization is the cornerstone and the primary reason for the creation of blockchain. Security is an essential feature to ensure that the blockchain structure operates correctly, and it is also key to building trust among users. Scalability, on the other hand, is necessary for this technology to continue evolving and for the number of users to keep growing. However, it remains the most challenging aspect to achieve and improve. The scalability trilemma is, therefore, a crucial consideration in the design and implementation of blockchain networks, requiring careful attention and strategic trade-offs.

The security of a blockchain is determined by the strength of its network and its capacity to prevent fraudulent activities and cyber threats. The security measures implemented by Blockchain technology include cryptographic algorithms for block validation, decentralization, and an immutable distributed ledger, as previously mentioned in the introduction. These integrated protections guarantee that each transaction is authenticated and unchangeable, safeguarding the system's integrity and users' trust.

Scalability, in contrast, pertains to the capacity of a Blockchain network to efficiently process a large number of transactions at a little expense. This feature is becoming increasingly crucial due to the exponential growth in the number of users and the pressing demand for efficient transaction execution. When examining the current characteristics of Layer 1 Blockchain networks, it becomes apparent that scalability is severely restricted. In reality, the majority of Blockchain networks have a limited capacity to process a small number of transactions per second. This constraint gives rise to bottlenecks that might impede the overall functioning of the system, resulting in delays in transactions and the imposition of exorbitant costs.

Specifically, how reported in the paper by Sguanci et al. (2021):

- Bitcoin has a transaction processing rate of 4.6 transactions per second (TPS).
- Ethereum has a transaction processing speed of roughly 14.3 transactions per second.
- In comparison, Visa has a transaction processing speed of about 1,736 TPS, with occasional peaks reaching 47,000 TPS.
- Bitcoin's blockchain produces a new block approximately every 10 minutes, with a block size (B) of 1 MB (1,048,576 bytes), but Ethereum's blockchain has a block size (B) of 12 MB.

The study highlights the significant disparity in scalability between Layer 1 Blockchain systems and traditional banking institutions. Consequently, there is an increasing demand for innovative technologies that significantly and definitively enhance this characteristic.

The issue of scalability arises at this point: to maintain a sufficient level of security, Blockchain networks typically establish a maximum block size in their protocols. This imposes a constraint on the number of transactions that can be handled within each block, resulting in slower execution and higher transaction fees. Essentially, achieving an appropriate equilibrium is necessary between the aspects of network security and scalability. Increasing the level of security poses challenges to achieving optimal network scalability, and conversely, decreasing security facilitates scalability. The engineering challenges in constructing blockchain networks are rooted in this trade-off, necessitating inventive ways to optimize both dimensions.

Exploring this feature, it's fundamental run a comparison between two consensus algorithms: PoW and PoS. The POW consensus system utilizes complex mathematical problems that necessitate extensive computing calculation, resulting in significant energy usage. This network has robust cybersecurity measures to protect against cyber-attacks and potential fraud. However, as a trade-off, it experiences a decrease in transactional capacity, leading to longer transaction propagation times and a less scalable network overall. The PoW, while providing security, has inherent limitations in terms of its capacity to scale efficiently. The POS consensus system employs fewer computationally demanding techniques, enabling it to process a higher number of transactions per second and achieve greater network scalability. Undoubtedly, the level of security is less when compared to POW algorithms. PoS provides increased scalability, but sacrifices a higher level of security, resulting in a distinct trade-off within the blockchain trilemma.

One of the cyber attacks that has been previously attempted is specifically double spending, topic discussed in depth in the study made by Jang and Lee (2020). Expanding the block size and increasing the amount of transactions a block can execute, can lead to longer transaction propagation and block transcription times. This, in turn, poses a danger to the integrity of the blockchain.

Specifically, a double spending (DS) attack refers to the deliberate attempt to circumvent the security measures of a blockchain system by duplicating a transaction that has already been executed and a corresponding item or service has already been received. Payment records are documented as transactions and distributed throughout a network through the existing sequence of events. Thus, in order to carry out a double spending assault, the attackers must replace the existing chain in the network with a new one after successfully acquiring the products or services.

5.2.1. Strategies for Scaling Networks

In this section, will be enumerated and examinated various options that can contribute to the enhancement of Layer 1 Blockchains scalability. One of the most comprehensive works in the accedemics literature in this direction appears to be the paper wrtitten by Rao et al. (2024), in which the above described problems of L1 solutions and some possible solutions are listed. However, the paper too, proposed solutions to the scalability problems of L1 solutions (Sguanci et al., 2021). One initial method to address the issue of scalability in blockchain networks is to increase the maximum block size (FaterCapital, 2024). This enhances the overall capacity of the network since it allows for the processing of a greater number of transactions within each block. Consequently, the velocity of transactions is enhanced, leading to a reduction in fee expenses. Nevertheless, this solution also possesses numerous drawbacks. In particular, the increase in block propagation time renders them more susceptible to cyber attacks, so diminishing the level of security. At the same time, rising the block size would result in a substantial rise in computational power requirements and energy consumption, potentially leading to centralization. Miners who have limited resources may face disconnection, resulting in a consolidation of power among a small number of prominent mining pools. Moreover, increasing the maximum block size entails a highly intricate procedure. The block size limit is determined by the protocol of each individual Blockchain network. Thus, in order to enlarge it, the protocol must be modified. This maneuver can only take place with the unanimous agreement of the Blockchain community in question. Another possibility for a change in the network's rules to occur occurs when some members of the blockchain community propose a change in its rules. If a portion or majority of the nodes vote against the change, but the rest of the community supports it, a hard fork occurs. This leads to the creation of two separate chains that share a common origin within the blockchain (Memon et al., 2018).

A hard fork occurs when a significant number or majority of the nodes vote against the change, while the remaining community members are in favor of it. This results in the formation of two distinct chains that have a shared starting point within the blockchain. A hard fork is the adoption of a modified version of the blockchain, where the nodes in the network unanimously decide to follow a new set of rules, resulting in the creation of a new chain that is incompatible with the old version (Memon et al., 2018).

An exemple in reality is Bitcoin Cash: certain individuals within the Bitcoin community initiated a hard fork to create Bitcoin Cash, with the aim of enhancing Bitcoin's capacity to handle a greater number of transactions. Bitcoin Cash has a block size limit of 32 MB, which is significantly larger than Bitcoin's limit of 1 MB (Forbes, 2023).

One more approach to enhance the scalability and efficiency of a network is to implement the sharding technique (Rao et al., 2024). The practice of sharding involves partitioning the data on the blockchain into smaller units known as 'shards' to make them easier to handle. A shard is an independent segment of the blockchain that can store distinct data pertaining to a subset of transactions or contracts. Shards are overseen by individual nodes or clusters of nodes, who have the duty of handling and storing the data within the designated shard. This method enables the network to carry out transactions concurrently, as each shard can be processed autonomously from the rest. Consequently, the network's total capacity experiences a substantial rise, enabling a higher number of TPS compared to a conventional blockchain where all transactions need to be processed one after another. Similarly to the prior situation, the sharding technique also has certain drawbacks: while the act of breaking the network into shards may appear to involve more nodes, one of the primary drawbacks is the lack of decentralization. Although dividing the network into shards may initially involve more nodes, it is crucial to ensure a high level of security and preserve the integrity of the blockchain. This requires careful coordination among the shards and the presence of an adequate number of participating nodes in each shard. Indeed, if a someone were to attempt to assault the network by compromising only one shard, substantial harm may be inflicted without the need to target the entire network. However, while employing the sharding strategy, the network becomes more vulnerable to cyber-attacks, necessitating the implementation of very particular and resilient cryptographic protocols for security purposes. Another crucial component of sharding is the administration of inter-shard transactions, which refers to transactions that include data situated in distinct shards. These transactions necessitate meticulous coordination to guarantee accurate recording across all shards involved, while maintaining the overall consistency and security of the network. To summarize, sharding is a feasible approach to enhance the scalability of blockchain networks. However, it necessitates a significant compromise between efficiency, security, and decentralization.

To further discuss potential methods for enhancing network scalability, we might consider solutions based on Directed Acyclic Graph (DAG) (Rao et al., 2024). These systems effectively enhance transactional efficiency by executing transactions in parallel, unlike the standard Blockchain network where transactions are added to a linearly distributed ledger. Transactions are depicted as nodes in a DAG, with each node referencing one or more preceding nodes. An example of DAG-based solutions in practice is the IOTA Tangle. *"The IOTA Tangle is purpose-built for the Internet of Things and is finely tuned for exceptional scalability, minimal resource usage, and robust data transmission security"* (Rao et al., 2024). IOTA employs a mechanism where every new transaction is required to validate a minimum of two preceding transactions. This approach obviates the necessity for miners and thus results in diminished transaction expenses. This method not only enhances the network's ability to handle larger amounts of data, but also enhances the network's energy efficiency, making it suited for IoT devices with limited resources (Rao et al., 2024). Additional prominent examples include Hashgraph and Phantom. Hashgraph employs a communication protocol known as "gossip about gossip" and a consensus mechanism termed "virtual voting" to attain rapid and secure agreement without the requirement for blocking. Hashgraph's high transaction speed and little propagation time make it well-suited for applications that necessitate swift transaction confirmation. Phantom, however, has a validation algorithm that offers enhanced adaptability in transaction handling, along with robust security measures to thwart cyber-attacks.

Undoubtedly, these technologies are continuously developing and a paramount emphasis on security is vital. Given that they lack a linear blockchain structure, consensus procedures are crucial to guarantee accurate recording of transactions. At present, the security level offered by these solutions is not as strong as that provided by traditional blockchain (Layer 1) network solutions. As a result, DAGs are more vulnerable to fraud and cyber assaults. Another crucial aspect that necessitates the development of these systems is their compatibility with conventional blockchain networks, enabling seamless communication and collaboration without compromising network security and efficiency.

Off-chain transactions offer another viable alternative for enhancing scalability (Rao et al., 2024). Thanks to the latter, it is feasible to execute a significantly greater number of transactions without overburdening the network. Indeed, in this particular system, transactions occur off the primary blockchain, so decreasing the burden on the network and enhancing overall efficiency. An illustrious illustration is the "Lightning Network": an alternate off-chain conduit for the Bitcoin network that facilitates direct communication between two nodes, enabling transactions to be processed swiftly and inexpensively.

The Lightning Network is a user-created payment channel that facilitates off-chain transactions. These transactions are only recorded on the main blockchain once the channel is closed, resulting in aggregated transactions (Sguanci et al., 2021). The Lightning network serves as an off-chain solution for Bitcoin, while the Raiden network fulfills a similar role for Ethereum. The approach is identical to the Lighting network, with the distinction that payment channels established between two nodes can also convey information regarding smart contracts. This technology has a huge impact on the role of miners by greatly reducing transaction costs through off-chain execution. Furthermore, this framework also promotes the feasibility of micropayments. Off-chain transactions, like DAG-based solutions, are technologies currently being tested and require additional development, particularly in terms of security. The security of funds in off-chain channels relies on the correct execution of protocols and the mutual agreement of both parties to terminate the channel together. Furthermore, there are apprehensions regarding centralization, since nodes that oversee a substantial number of channels may acquire excessive control over the network.

An alternative approach could involve the implementation of what are known as "sidechains".

Sidechains are autonomous blockchain networks that are linked to the primary blockchain. This connection enables the flow of data between the primary blockchain and the sidechains. In addition to enhancing the overall scalability of the network, their primary objective is to enable the deployment of specific applications and manage heavy workloads without overwhelming the main blockchain. Specifically, sidechains facilitate the implementation of dApps that may necessitate substantial resources. By leveraging sidechains, these applications can function autonomously without impacting the efficiency of the primary blockchain. Indeed, this characteristic is crucial for evaluating the effectiveness of Blockchain networks, as we will explore further on. Sidechains effectively process a greater number of transactions at a reduced expense compared to the primary network. Simultaneously, they ensure a relatively high degree of security by delegating security procedures to the main network. Sidechains are technologies that function semi-independently. However, in order to maintain the same level of security as the main blockchain, it is necessary to have a flawless implementation of the transfer protocols between the sidechain and the main network, as well as complete trust in the nodes that validate transactions on the sidechain.

We will now examine cross-chain technology as the final option. Cross-chain technologies facilitate the exchange of data and information between different Blockchains, effectively connecting them. This approach enhances the versatility of the Blockchain by enabling users to utilize various functionalities of different Blockchains without the need to switch platforms. Cross-chain solutions enhance network scalability by distributing the transaction load across different networks, so alleviating congestion and enhancing overall efficiency, instead of overwhelming a single blockchain with all transactions. The Polkadot protocol is an instance of this technology, enabling seamless communication and data transfer between distinct blockchains by utilizing a parachain architecture. The regulatory framework governing the Polkadot ecosystem is referred to as the "Relay Chain." It assumes the crucial role of ensuring the security, consensus, and governance of all parachain networks. The consensus technique employed by the "Relay chain" and thereafter utilized by all parachains is referred to as Nominated Proof-of-Stake (NPoS). The NPoS method is a modified version of the PoS algorithm. In NPoS, validators are selected based on the nominations they receive from other network users, known as nominators, in addition to the number of tokens they have staked. Nominators choose validators whom they consider reliable and invest their cryptocurrency to support these validators. Parachains are autonomous chains that run alongside the "Relay chain" but have a strong connection to it. Essentially, parachains are akin to sidechains but with a lesser level of interdependence. Once again, just like in the previous solutions examined, it is crucial that the security protocols are sufficiently effective to guarantee the network's integrity.

5.3. The Layer 2 Landscape: Unlocking Blockchain's Potential

Layer 2 solutions emerge from the aforementioned responses to scalability. Indeed, these solutions employ one or many of the principles we previously outlined. In this section, we will thoroughly examine the most often used approaches to explore and comprehend the factors that are crucial in determining the success of these initiatives. Layer 2 solutions, are a notable progression in blockchain technology. They are specifically developed to tackle scalability and efficiency challenges that affect Layer 1 blockchains. The decision to study Layer 2 solutions was based on the consistent evidence that, independent of the specific type of L2 solution used, network scalability performance is consistently superior to that of L1 solutions. As previously mentioned, there is an ongoing discussion in the scientific literature regarding the impact of processing additional transactions on the level of security. While Layer 2 technologies offer advantages in terms of speed and cost, their integration must be approached cautiously to ensure the network's security and trust are upheld. Layer 2s are valuable because they address the scalability issues of existing Layer 1 blockchains and enhance their efficiency. This section emphasizes the significance of Layer 2 solutions in the contemporary blockchain landscape, where there is a continuous rise in the need for quick and cost-effective transactions.

A Layer 2 system refers to a protocol that is constructed on top of an already existing Layer 1 blockchain. Layer 2 solutions, irrespective of the particular technology employed, provide transaction processing outside the primary network or in conjunction with the primary blockchain through an external system. By adopting this approach, the burden on the primary network is reduced while still maintaining the network's integrity, but with a lower level of security. These technologies allow for increased transaction capacity while minimizing costs. Consequently, the network's efficiency is significantly enhanced. By reducing the burden, Layer 1 blockchains can sustain optimal performance despite a growing number of users and transactions. This enables networks to facilitate broader acceptance and more effectively meet the increasing need for transaction capacity.

There are multiple classifications for Layer 2 systems in the scientific literature. The proposed taxonomies exhibit significant similarities, but in our perspective, the publication by Gangwal et al. (2023) has presented the most extensive and exhaustive effort to date. This paper provides a comprehensive analysis of many Layer 2 solutions, outlining their individual merits and drawbacks. It offers valuable insights for the practical application and assessment of these solutions. Layer 2 techniques are specifically categorized into three distinct families:

- **Channels**: Two users can establish channels to facilitate transactions between them. Channels enable the processing of transactions outside the main network while ensuring the same level of security as transactions within the main network. There exist two primary categories of channels: state channels and payment channels. The primary distinction between the two is that the former are "generalized versions" while the latter are more focused on payment-related aspects.As indicated in the study by Gangwal et al. (2023), a state channel facilitates the transfer of states (information) between two users. The most advantageous use cases for state channels are typically found in scenarios such as voting or auctions, where the flow of information is essential. The transfer occurs beyond the central network and is regulated by a smart contract. Users sign transactions and record them with each other. Ultimately, the conclusive status is released on the primary Blockchain. The primary benefit is that off-chain transactions are significantly faster than on-chain ones. Another benefit is the substantial reduction in the strain on the main network, resulting in an overall boost in transactional efficiency. This enhancement greatly enhances the user experience and augments the network's capacity to process transactions.Payment channels, in contrast, serve the only purpose of facilitating faster and more cost-effective transactions, including those involving little amounts of money. Once again, the transaction, or payment, occurs outside of the central network and is regulated by a smart contract. More precisely, two users immobilize funds within the contract, which establishes a specific time limit for expiration and a delay for settlement. The channel can only be closed once the transaction is done. If there are no money left, the channel will terminate automatically without delay. However, if there are money in the payment channel, the recipient has the opportunity to claim them until the settlement delay expires. The primary benefits are identical to those of payment channels. However, payment channels offer an additional advantage in the form of substantially lower fees as compared to traditional on-chain transactions. Payment channels are an exceptionally effective alternative for frequent transactions involving modest amounts. Moreover, the capacity to decrease fees and accelerate transaction durations renders these channels exceptionally valuable for microtransactions, which might be ineffectual and costly on a primary blockchain.

- **Sidechains**: Sidechains are autonomous blockchains that operate concurrently with the main blockchain while remaining interconnected to it, as explained in the preceding chapter. More precisely, they utilize a two-way bridge, known as a two-way peg, to facilitate the transfer of funds between the secondary blockchain and the primary blockchain. Side-chains offer not just the traditional benefits of off-chain solutions, but also provide enhanced flexibility and separated security. Indeed, in order to maintain an equivalent level of security to the primary blockchain, it is crucial to have a seamless system of transfer protocols connecting the sidechain and the main network. However, it is equally important to note that any problems that occur on the sidechain do not have any negative impact on or harm the main blockchain. This characteristic makes the sidechain a secure environment for experimenting with new applications. Sidechains enable the development and testing of new functionalities prior to their implementation on the primary chain. In addition, sidechains can be categorized into two types: custodial and noncustodial sidechains. The distinction resides in the fact that custodial sidechains utilize their own consensus algorithms and security standards to exchange data and funds, whereas noncustodial sidechains safeguard data and funds through smart contracts on the main network. This differentiation enables more adaptability in the implementation of sidechains based on individual security and operational requirements.

- **Cross Chain**: the basic aspects of cross-chains were thoroughly explored in the previous chapter. Cross-chains facilitate the transfer of assets across distinct blockchains. Each Blockchain may include a distinct consensus process and level of security, resulting in cross-chains being vulnerable to significant risks. To address this, it is necessary to implement precise and robust transfer rules. The study made by Gangwal et al. (2023) presented two primary methods for implementing cross-chains: the "Notary scheme" approach and the "Blockchain of Blockchains" approach.The first aspect pertains to specific nodes, known as notaries, whose function is to authenticate and authorize transactions between Blockchains. The second strategy, conversely, involves directly linking multiple Blockchains to create a larger and more cohesive network. The primary benefits of utilizing blockchains include enhancing scalability and transaction speed through the distribution of workload across multiple blockchains. Additionally, blockchains enable decentralized applications (Dapps) to operate on various blockchains and serve as an intermediary platform for transactions between different blockchains. This strategy enables the creation of a highly integrated and adaptable blockchain ecosystem that can effectively cater to various needs and applications.

Upon conducting a thorough analysis of the benefits and drawbacks of the aforementioned families, together with an examination of the primary projects now available, it becomes evident that side chains predominantly control the current L2 environment. Due to these reasons, the decision was made to redirect the attention towards this particular category in order to identify its unique characteristics for the purpose of conducting an evaluation.

The table 5.2 reports some technologies utilized in significant Layer-2 projects.

Project	Technology Utilized
Optimism	Optimistic Rollups
Arbitrum	Optimistic Rollups
Mantle	Optimistic Rollups
Polygon	A mix between Rollups and Plasma Chain

Table 5.2: L2 Projects and Technologies Utilized

The current table indicates that the leading Layer-2 initiatives employ Rollups technology to enhance the scalability of the underlying network (Layer-1). Additionally, Plasma-chains solutions are also widely utilized. Both Rollups and Plasma Chains are categorized as non-custodial sidechains.

Rollups solutions enhance network scalability by processing off-chain transactions and subsequently registering successfully executed transactions on the core network. There exist two categories of Rollups: zero knowledge Rollups (ZK) and Optimistic Rollups. In particular, in the paper by Neiheiser et al. (2023) are discussed in depth the functioning of ZKs and Optimistic rollups. The primary distinction between the two classifications of Rollups resides in the approach to transaction validation.

Optimistic Rollups include the processing of transactions outside the primary network, after which they are transmitted to the main-chain in condensed blocks. The validations in this type of Rollup are considered valid from the outset, hence the name "Optimistic." Indeed, the transactions are confirmed after they occur, which greatly enhances the speed of the transactions and reduces the computing burden. However, this also exposes the network to a lower level of security. In order to guarantee security, there exists a designated period of time known as the dispute period, wherein any participant has the ability to contest the legitimacy of transactions by providing evidence of fraudulent activity. If fraud is truly identified, the perpetrator is fined and the status is rectified. The implementation of this security protocol results in a delay in the withdrawal of funds, often taking around 7 days. A plentiful amount of resources is necessary for this particular Rollup due to the ongoing need for fraud detection. Optimist rollups offer a significant benefit by providing the capability to manage intricate "smart contracts."

Similarly, in Zero Knowledge rollups, transactions are consolidated and executed outside of the main blockchain. However, in this scenario, it is necessary to authenticate transactions prior to their transmission to the primary blockchain. Zero-knowledge proofs are employed to authenticate transactions, which is why this group of rollups is named as such, while keeping transaction specifics undisclosed. Subsequently, a cryptographic verification must be transmitted to the primary network, confirming the legitimacy of the transactions. Therefore, ZKs offer a higher level of security compared to Optimistic. Even in the context of Rollups technologies, there is no single solution that outperforms others in all aspects. Specifically, while ZKs offer superior security and privacy, they require more computational power, leading to increased energy consumption. Additionally, ZKs are not capable of handling complex smart contracts like Optimistic. Furthermore, the introduction and continuous management of Rollups necessitate a sophisticated technical infrastructure, hence amplifying the requirement for meticulous maintenance and substantial technology resources.

In summary, due to the aforementioned causes, Rollups necessitate substantial expenditures for maintaining the core network.

Plasma chains solutions enable the establishment of several blockchains that are subordinated to a primary blockchain, structured in a hierarchical manner similar to branches of a tree. Each secondary blockchain, referred to as a Plasma chain, has the ability to divide into further smaller blockchains known as daughter networks. Every Plasma chain autonomously handles its own block validation procedure, apart from the parent chain. Nevertheless, the primary blockchain governs and orchestrates the overall operations of Plasma chains. This system is plagued by issues such as escalating expenses for data storage, demanding processing needs, and a lack of support for real-time transactions.

Plasma enhances the security of sidechains by mandating a security repository on the main blockchain and directly transmitting transaction data to it, akin to Optimistic Rollups. If there is any misconduct, the status is reevaluated and the security deposit is fined, using a similar approach as in Optimistic Rollups. Withdrawals from the Plasma chain require a duration of seven days to be fully processed, however, they benefit from the security assurances provided by the main blockchain. Nevertheless, Plasma's compatibility with numerous smart contract transactions on sidechains is limited, hence restricting its utilization to a select few applications. Plasma chains operate separately from the main-chain, resulting in a minimal cost for maintaining the main network and providing significant scalability possibilities. Nevertheless, the level of security offered by this layer-2 technique is considerably inferior to the other available options. Furthermore, Plasma Chains can be utilized to create and evaluate novel applications inside a regulated setting, hence minimizing the potential for introducing weaknesses in the primary blockchain. This method enables the ongoing development and implementation of new technologies while maintaining the overall security of the network. The next sections will present recommended methods for assessing tokens associated with Layer-2 initiatives.

5.4. L2 valuation

Having thoroughly analyzed how these solutions work and the technologies they use in the previous chapters, key parameters have been identified that can provide insights into the value of the project and, consequently, the associated token. These parameters are reported in Table 5.3 with the area of interest they cover.

Through the analysis of the valuation discussed in Chapter 4 and the assessment of Layer 2 solutions, specific parameters have been identified as particularly suitable for conducting a relative valuation within the L2 space. These parameters, derived from a thorough examination of both the L2 projects and token metrics, provide valuable insights into the key drivers of value in the L2 ecosystem.

To achieve a comprehensive evaluation, the project will be assessed from multiple angles, utilizing these carefully selected parameters, which are believed to offer the most significant insights into the overall token value. In the sections that follow, the identified parameters will be presented, along with detailed justifications for their selection, ensuring that the evaluation framework is both rigorous and relevant to the unique dynamics of L2 solutions.

Area of Interest	**Parameter**
User Adoption	Number of New Daily Unique Addresses
Transaction Efficiency	Transactions per Second (TPS)
Transaction Costs	Daily Gas Fees
Correlation with L1	L1 Price

Table 5.3: L2 Parameters and Areas of Interest

Number of New Daily Unique Addresses It offers valuable insights into the level of user engagement and adoption of a blockchain project. This metric has been chosen as a key indicator because it reflects the platform's growing user base and activity. By quantifying the number of unique blockchain addresses interacting with the network, it becomes possible to gauge how well the project is being adopted by its user community.

A high number of unique addresses typically signifies a robust level of user engagement, indicating strong adoption and sustained interaction within the network. In this context, blockchain addresses can be compared to traditional bank account numbers, such as IBANs, where each address uniquely identifies a user within the blockchain ecosystem. Tracking the number of unique addresses per day allows for a clearer view of how user participation evolves over time, and how it correlates with daily price fluctuations.

As highlighted by Liebi (2022), user adoption over the medium to long term is a critical competitive advantage for blockchain projects, as it demonstrates sustained interest and usage. Therefore, monitoring the growth of unique addresses provides a useful perspective on the project's potential to maintain and expand its user base, which is a vital component of its overall value proposition.

It will be particularly interesting to incorporate this parameter, as paper Şoiman et al. (2023) pointed out that both transactions and active addresses can have a potentially negative impact on token value. According to the study, an excessive increase in these factors could indicate speculative activity or network overcrowding, reducing investor confidence and leading to a decrease in the perceived value of tokens. Therefore, analyzing these variables is crucial to better understand market dynamics and the stability of token value over time.

Throughput per second (TPS) It provides a clear measure of how efficiently a Layer 2 solution can process transactions, which is directly tied to its scalability. Indeed, the core objective of L2 systems is to increase the scalability of the base layer (in this case, Ethereum) by improving transaction speed and enabling the network to handle a significantly higher number of transactions. The most relevant metric for assessing this aspect is transactional throughput, or the number of transactions processed daily by the L2 network (Pakhnenko et al., 2022; Sguanci et al., 2021). TPS measures how many transactions the network handles each second, offering insight into the platform's transaction speed and overall performance.

Daily Gas Fees When evaluating the scalability of Layer 2 systems, it is important not only to focus on transaction speed but also on the associated commission costs. Layer 2 solutions are specifically designed to reduce transaction fees (known as gas fees) on the main chain, which is a key component of network scalability. To assess this aspect quantitatively, we calculate the Daily Gas Fees, which measure the transaction costs on Layer 2 networks and their impact on the Ethereum main chain. Gas fees represent the cost users pay to execute transactions on the blockchain. These fees are required to compensate the validators for the computational power they use to validate transactions and secure the network. Gas fees are calculated using the following formula:

$$\text{Gas Fees} = \text{Gas Used} \times \text{Average Gas Price}$$

- **Gas Used**: The amount of computational resources required to process a specific transaction. This depends on the complexity of the transaction;

- **Average Gas Price**: The price users are willing to pay per unit of gas, often measured in gwei (1 gwei = 0.000000001 ETH). The gas price fluctuates based on network demand.

For Layer 2 projects, the Daily Gas Fees are calculated by extracting the total gas fees used for transactions on the Layer 2 network. These fees are then compared with the gas fees on Ethereum's main chain to determine the extent to which the Layer 2 system reduces the overall cost of transactions.

L1 Price A key metric for evaluating the correlation between Layer 2 projects and their underlying Layer 1 systems is the L1 price. This metric measures how fluctuations in the price of the L1 system (such as Ethereum or another blockchain) influence the price movements of the L2 token (Corbet et al., 2022; Şoiman et al., 2023). A strong correlation suggests that the L2 token's value is closely aligned with changes in the L1 network, while a weaker correlation indicates more independence from L1 price dynamics. Understanding this correlation with the L1 system is crucial for assessing the interdependence between L2 and L1 networks. L2 projects are built on L1 infrastructure, so their market performance is often affected by the success and fluctuations of the base layer. A high correlation may indicate that the L2 project is sensitive to L1 market changes, while a lower correlation might reflect a more distinct value proposition for the L2 token. This analysis provides important insights into how price shifts in L1 networks might impact the associated L2 tokens, aiding in the evaluation of the overall market behavior and resilience of L2 solutions.

These parameters will be valuable for conducting a relative valuation by proposing a relevant multiple. Furthermore, they will be tested empirically to assess whether they have a statistically significant impact on the market capitalization of each project.

6 | DEX Analysis

6.1. Paper Review

The table 6.1 contains a collection of the papers that have been used to conduct the literature review. The process that led to the selection of these papers is thoroughly discussed in the methodology section (Paragraph 2.1.4) and visually outlined in the PRISMA diagram (Figure 2.4). This approach ensures a structured and transparent selection process, offering a comprehensive overview of the research landscape relevant to the study.

This table offers a focused exploration of research papers dedicated to DEX and their role in the evolving blockchain ecosystem. The papers investigate a wide range of DEX-specific topics, including the technical foundations, smart contracts, and Automated Market Makers (AMMs), which are crucial to the functioning of DeFi markets. Several papers emphasize the development of DEX infrastructures, explaining how they enable peer-to-peer trading and the conversion of illiquid markets into liquid ones. The discussion extends to the challenges of scalability and cross-chain interoperability, as exemplified by protocols like “Mixta,” which aim to enhance the flexibility and speed of decentralized exchanges. The table also includes studies that focus on security risks associated with DEXs, such as price slippage, Maximal Extractable Value (MEV) attacks, and the detection of scam tokens. These papers highlight the vulnerability of DEXs to certain exploitation tactics and underscore the need for improved regulatory frameworks and enhanced user protections. Overall, this collection of papers provides a comprehensive look at the mechanisms driving DEX innovation, the key technical hurdles they face, and the importance of creating secure and scalable platforms for decentralized trading.

Summary of Research Papers on Decentralized Exchanges

Title	Author	Journal	Year	Comment
Economic Analysis of Decentralized Exchange Market with Transaction Fee Mining	Zhang, Hongbo and Fan, Sizheng and Fang, Zhixuan and Cai, Wei	BSCI 2022 - Proceedings of the 4th ACM International Symposium on Blockchain and Secure Critical Infrastructure	2022	Examines the mechanism of "transaction fee mining" and its critical role in the success of decentralized exchange markets. Discusses the disparity in transaction costs and the stickiness of consumers.
DEX: A DApp for the decentralized marketplace	Dai, Chris	Springer	2020	Provides a detailed explanation of how decentralized exchanges (DEX) function, highlighting the conversion of illiquid markets into liquid markets through peer-to-peer trading.
spryDEX: Decentralized Exchange for Cryptocurrencies using Blockchain	Ghodake, O.A. and Samant, R.M. and Rahane, W.P. and Madanepatil, A.A. and Patil, A.M. and Makwani, S.M.	2023 7th International Conference on Computing, Communication, Control And Automation (ICCUBEA)	2023	Explains the functioning of smart contracts on decentralized exchanges (DEX) in detail.
Decentralized Finance and Cross-Chain Interoperable Automated Market Maker - Using BlockChain	Decentralized Finance and Cross-Chain Interoperable Automated Market Maker - Using BlockChain	2nd International Conference on Emerging Trends in Information Technology and Engineering, ic-ETITE 2024	2024	Introduces a new protocol called "Mixta" to address scalability issues in decentralized exchanges (DEX). Provides an in-depth analysis of different types of Automated Market Makers (AMM).
Automated Market Makers	Pourpouneh, M. and Nielsen, K. and Ross, O.	Department of Food and Resource Economics (IFRO), University of Copenhagen	2020	Offers the first detailed structure regarding the coding of Automated Market Makers (AMM), focusing on the technical aspects of their implementation.
Enabling Technologies for Web 3.0: A Comprehensive Survey	Md Arif Hassan and Mohammad Behdad Jamshidi and Bui Duc Manh and Nam H. Chu	Proceedings - IEEE Symposium on Security and Privacy	2023	Focuses on the characteristics and competitive advantages of Web 3.0 technologies, discussing their impact and potential to drive innovation in the decentralized exchange market.
High-frequency trading on decentralized on-chain exchanges	Zhou, Liyi and Qin, Kaihua and Torres, Christof Ferreira and Le, Duc V. and Gervais, Arthur	Proceedings - IEEE Symposium on Security and Privacy	2021	Examines the impact of price slippage on the overall security of decentralized exchanges (DEX), with a focus on high-frequency trading on on-chain exchanges.

Title	Author	Journal	Year	Comment
Decentralized Exchange Transaction Analysis and Maximal Extractable Value Attack Identification: Focusing on Uniswap USDC3	Choi, Nakhoon and Kim, Heeyoul	Electronics (Switzerland)	2023	Conducts a comprehensive study on the topics of bots and Maximum Extractable Value (MEV) on decentralized exchanges, highlighting criticisms and how they negatively impact trust among users, market mechanisms, and transactions.
Trade or Trick? Detecting and Characterizing Scam Tokens on Uniswap Decentralized Exchange	Xia, Pengcheng and Wang, Haoyu and Gao, Bingyu and Su, Weihang and Yu, Zhou and Luo, Xiapu and Zhang, Chao and Xiao, Xusheng and Xu, Guoai	Proceedings of the ACM on Measurement and Analysis of Computing Systems	2021	Argues that one of the causes of token scams is the lack of structured regulation for token listing on exchanges, with a focus on identifying and characterizing scam tokens on the Uniswap decentralized exchange.
Application and evaluation of payment channel in hybrid decentralized ethereum token exchange	Xuan Luo and Zehua Wang and Wei Cai and Xiuhua Li and Victor C.M. Leung	Blockchain: Research and Applications	2023	Discusses the advantages and disadvantages of decentralized exchanges (DEX) compared to centralized exchanges (CEX) and hybrid exchanges (HEX).
Blockchain Based Future Banking by Decentralized Exchanges	Raman, Ramakrishnan and Mary Rexy V. Arul and Viswanathan, C. and Shrivastava, Ankit and Ganesh, E. N.	2023 International Mobile, Intelligent, and Ubiquitous Computing Conference (MIUCC)	2023	Explores the possible future development of decentralized exchanges (DEX) in banking, highlighting potential applications and challenges.
SushiSwap and Vampire Attacks in Decentralized Finance (DeFi)	Cryptopedia Staff	Gemini.com	2023	Analyzes "vampire attacks" in the context of decentralized finance (DeFi), particularly focusing on the competition between UniSwap and SushiSwap.

Table 6.1: Summary of Research Papers on Decentralized Exchanges

6.2. DEX: Functionality and Dynamics

The interaction between DEX environment and blockchain, if specific terms and conditions are met, takes place via smart contracts in an automated manner.

There are essentially three phases of an exchange:

1. Discovery of the asset price;
2. Matching of the exchanges according to the "bid and offer" dualism;
3. Clearing of trades.

The simplified logic of how smart contracts work, given in the document "spryDEX: Decentralised Exchange for Cryptocurrencies using Blockchain" Ghodake et al. (2023) is described below:

Algorithm 6.1 Smart Contract Logic

```
receive funds
check transaction status
if transaction happened then
    forward funds to destination
else
    return funds to sender
end if
```

A direct interaction between a liquidity provider and a liquidity acquirer is the foundation of the DEX's operation. A liquidity provider is a user who provides liquidity in the market by putting financial assets at their disposal. Essentially, it provides the funds that other users can use to exchange other assets. On the other hand, a liquidator is a user who trades an asset for sale. There are two mechanisms for discovering the price of the asset:

1. **Order Book**: a list in which the quantities and prices of a list of purchase and sale orders for a specific asset are provided. The role of liquidity providers is to continuously quote bid (offer) and query (question) prices. The liquidity providers compete among themselves to attract liquidity acquirers. In contrast, liquidators accept the opportunity to purchase or sell at the best available price in the order book. This type of order is immediately paired with the existing orders of liquidity providers to complete their transactions.

2. **Automated Market Maker**: utilises a predetermined algorithm to automatically determine asset prices, eliminating the need for manual orders from liquidity providers. Liquidity providers deposit their assets in liquidity pools and are not required to actively monitor the market in order to adjust prices. On the other hand, liquidators may exchange directly with the liquid in the pool, which is facilitated by the AMM.

In the document by Dai (2020) the detailed operation of a decentralised swap within the DEX is examined. The function that governs a decentralised swap is referred to as a "atomic swap", which is a code that enables two users to exchange cryptographic assets between themselves. Indeed, in DEXs, users exchange assets directly within their wallets without the involvement of a financial intermediary. One of the greatest advantages of DEXs in comparison to traditional centrally managed exchange systems is their increased resilience and less vulnerability to attacks that aim to compromise the financial system and execute fraud. Indeed, decentralised exchanges, which are based on Blockchain technology, do not rely on centralised databases that are frequently exposed to manipulation by malicious actors. Instead, they record transaction data on a network of nodes using precise and robust cryptographic mechanisms to ensure the authenticity of transactions and preserve their security. Another advantage that these environments possess in comparison to traditional centralised systems is definitely related to transparency. In traditional systems such as banks, consumers suffer from "information asymmetry," as they lack access to a wealth of information regarding the bank's liquidity status, the complex process that regulates the successful completion of transactions, and, as a result, the commission and time associated with each transaction (particularly for international transactions). However, in DEX, users are able to observe all transactions that are processed, know the costs, and independently verify the authenticity of the transactions due to the presence of an immutable record. This characteristic leads to a significant increase in user confidence. Furthermore, the DEX significantly increases financial accessibility, accessible to anyone with an internet connection.

There are numerous obstacles that prevent users from accessing traditional banking systems. The paper by Raman et al. (2023) argued that these limitations penalise users with less stable profiles, who are damaged by limited liquidity guarantees or the absence of permanent property.

Continuing with the benefits provided by DEX, it is crucial to emphasise how these platforms enhance the efficiency of transactions. In traditional banking transactions, the number of parties involved is numerous, which results in processing delays due to factors such as manual procedures and the necessity of communication between various banks. Not only do these transitions increase execution times, but they also increase transaction costs. By eliminating intermediaries, DEXs reduce processing times by automating the execution of transactions through smart contracts and significantly reducing commissions. The advantages of DEX are even more apparent in international transactions.

Furthermore, the study mede by Dai (2020) discussed how DEXs convert traditionally unliquid markets into liquid markets through peer-to-peer trading. For instance, in the art market, which is typically characterised by a small number of institutional investors who participate in auctions, DEX enables investors to invest in art fractions, thereby increasing financial inclusion. This implies that any individual is permitted to invest in an asset based on their own availability, thereby increasing the liquidity of the market through the continuous exchange of assets among various users. The greater liquidity of the assets allows them to acquire value intrinsically, as the value of the tokens is derived from the value of the underlying asset and the liquidity premium generated by the reduction of commissions.

However, DEX also offer cons. Scalability is one of the primary issues: platform congestion can result in slowdowns and delays in transactions, which in turn raises commission costs. Another critical point pertains to regulation: the challenge of regulating decentralised finance in a manner that safeguards financial innovation and empowers users' decision-making power is one that governments and regulators worldwide are currently endeavouring to resolve. The future of the regulatory environment for DEX will depend on the successful establishment of a balance between supervision and innovation.

The topic of scalability will be one of the topics that will be extensively discussed in the future in scientific literature. Innovative solutions aim to enhance the performance of DEX while maintaining the other fundamental qualities. An example is the paper by Sarumathi et al. (2024), which introduced a new protocol called "Mixta". The Mixta protocol is designed to redefine cross-chain compatibility, enabling seamless navigation and transactions across multiple blockchain networks, thereby enhancing the comprehensive accessibility of users. Three critical components are seamlessly integrated to facilitate secure and efficient cross-chain transactions: Layer Zero Messaging, AMM and Liquidity Aggregation. These components work together to increase liquidity across a variety of chains, enable automated exchanges through AMM algorithms, and ensure reliable communication between blockchain networks, thereby ensuring a secure and optimal user experience.

In order to ensure that DEX continues to expand in terms of user engagement, it is necessary to provide a comprehensive financial education. This will enable users to fully comprehend both the benefits and risks associated with these environments, thereby promoting the informed and conscious use of decentralised platforms.

6.2.1. CEX vs DEX

Luo et al. (2020) provided a comprehensive comparison between CEX and DEX. The centralised nature of CEXs means that users must deposit their tokens at an address provided by the CEX, making the exchange the custodian of users' assets. Users derive two primary benefits from this centralised system. Initially, CEXs provide a rapid trading experience by directly updating the CEX's database with each transaction, eliminating the necessity for blockchain interaction. This results in a substantial reduction in transaction latency periods. Secondly, CEXs enable users to conduct transactions in a private manner, as the blockchain does not publicly display the trading records of a specific user.

Nevertheless, the centralised nature of CEXs is in direct opposition to the decentralisation ethos of the blockchain and distributed ledgers. CEXs are inherently susceptible to cyber attacks due to this form of centralisation. In the past, there have been numerous instances of hacker attacks that resulted in the theft of substantial quantities of cryptocurrency from these centralised exchanges. Additionally, service disruptions may occur in CEXs, which may affect users' capacity to conduct transactions and access their funds.

In contrast to CEXs, DEXs enable users to maintain control over their digital assets by serving as transparent intermediaries for token merchants. Smart contracts, which are bytecode programs that are registered on the blockchain and executed autonomously without third-party intervention, are used to implement trading procedures in DEXs. Users implement their transactions by transmitting a transaction to the blockchain, which initiates a procedure specified in the smart contract.

The potential security issues associated with CEXs are significantly mitigated by this configuration, as there is no singular point of control or failure. Nevertheless, DEXs pose two primary critical issues. Initially, token traders face difficulties with identifying suitable counterparties for their transactions due to the absence of an order matching service. The merging of buy and sell orders is facilitated by a centralised order book in CEXs. In contrast, DEX requires users to manually identify appropriate transactions, a process that can be time-consuming and inefficient. This is the rationale behind the implementation of the AMM mechanism.

Secondly, the Ethereum Virtual Machine and the PoW consensus algorithm, as well as the low transaction throughput of Ethereum, limit the scalability of the blockchain. Consequently, all trading requests in DEX are transmitted to the blockchain as blockchain transactions. This can result in increased petrol costs and lengthier transaction confirmation times, rendering transactions on DEX less efficient than those on CEX.

The Paper by Luo et al. (2020) argued that, in order to enhance the user experience and confront these obstacles, it is suggested that conventional HEX be expanded by incorporating a new layer of payment channels. This method has the potential to alleviate transaction congestion on the blockchain, as well as reduce petrol fees and transaction confirmation latency. The implementation of a payment channel system could enhance the efficiency and scalability of token trading by facilitating a more seamless user experience.

6.3. The Role of Automated Market Maker

AMM are emerging to be vital protocols within Decentralised Exchanges, resulting in a revolutionary transformation in the dynamics of cryptocurrency transactions. These

AMMs enable the exchange of digital assets without the need for authorisation, operating automatically through the use of liquidity pools, rather than relying on a traditional market of buyers and sellers. The AMM provide a decentralised platform that enables users to conduct trading operations in a continuous and uninterrupted manner by utilising intelligent contracts. The integration of AMMs within DEXs surpasses the traditional order book, revolutionising market dynamics and providing a more efficient and decentralised paradigm for token transactions. At the core of an AMM is a sophisticated and autonomous trading mechanism that has been meticulously designed to optimise cryptocurrency transactions. This mechanism guarantees that the price of assets is consistently updated in accordance with the quantity of liquid assets in the liquidity pool, thereby significantly enhancing market transparency and fluidity. Conversely, exchanges that rely on order books have been found to be unsuitable for the blockchain environment due to usability and scalability issues that stem from a lack of liquidity. These issues encompass the necessity of manual order updates and the challenge of managing large volumes of real-time transactions, which can result in delays and inefficiencies. In order to address these challenges, a decentralised exchange based on AMM was proposed, which utilises advanced algorithms to ensure better liquidity and transaction management.

Automated Market Makers in DEX enable users to exchange digital assets through a token pool, which is referred to as a liquidity pool. Users have the ability to contribute tokens to these pools, typically in equal quantities of two distinct tokens. Therefore, the price of tokens within the pool is determined by a predetermined mathematical formula. The liquidity providers fulfil an essential role by contributing their funds to these pools and enabling the smooth execution of transactions, thereby earning commissions in exchange. Traders who employ the pool for their transactions are responsible for paying commissions. This unique incentive structure encourages active community participation and increases liquidity, thereby contributing to the success of AMM.

The operation of AMM is based on intricate mathematical mechanisms that are designed to automatically regulate asset prices in accordance with the liquidity available in a specific pool. The cost product formula, represented as x times y = k, is the foundation of this system. Here, x and y represent the quantities of the two assets in the liquidity pool, and k is a cost that represents the product of these quantities. For example, during a swap operation between ETH and UNI, the quantity of ETH increases when a user adds more ETH to the pool, resulting in a decrease in the available quantity of UNI to maintain the current value k. This automatic rebalancing of the quantities in the pool determines the adjusted asset price. After the user approves the transaction, the AMM algorithm calculates the impact on the liquidity pool's reserves, deposits the acquired tokens in the pool and transfers the equivalent value of the other asset from the pool to the user's wallet. This process demonstrates the automated precision of AMM in the execution of transactions and the maintenance of liquidity through an algorithmic protocol based on smart contracts. Smart contracts ensure that all operations are conducted in a secure and transparent manner, thereby eliminating the need for intermediaries and reducing transaction times. Furthermore, the utilisation of these intelligent contracts enables a greater degree of efficiency and fluidity in the cryptocurrency market, thereby fostering a more inclusive and accessible trading environment.

The document by Pourpouneh et al. (2020) in the written language, opening the way for subsequent research and significant contributions in the field. From those, the document by Sarumathi et al. (2024) stood out for conducting a comprehensive analysis that demonstrates the various types of existing AMMs, providing a comprehensive overview of their characteristics and functional dynamics.

Automated Market Makers Types and Their Equations

	AMM Type	Equations of AMM	Description
1	CPMM	$x \cdot y = k$	Establishes token prices based on the product of reserves x and y, user-friendly and accessible.
2	CSMM	$x + y = c$	Utilizes a sum-of-two-variable approach, transparent pricing, but limited scalability due to a fixed sum structure.
3	CFMM	$x^2 + n \cdot D \cdot x = D \cdot A^2$	Blends CPMM and CSMM, mitigates slippage in stable coin trading, but introduces complexity in managing dual functionalities.
4	CMMM	$(x \cdot y \cdot z)^{1/3}$	Enables custom pools with varying token percentages, addressing impermanent loss concerns, but demands careful management of token weights.
5	vAMM	$(x - z) \cdot (y + (a - \text{spread} - \text{fee})) = c$	Refines CPMM, eliminates impermanent loss, shifts focus to traders, introducing governance consideration.

Table 6.2: Types of Automated Market Makers with their respective equations and descriptions by Sarumathi et al. (2024)

The table 6.2 illustrates a variety of Automated Market Maker frameworks, including CPMM, CSMM, CFMM, CMMM, and vAMM, each of which is distinguished by complex mathematical formulations. The CPMM ensures stability by producing a constant product of asset prices through nonlinear differential equations. The CFMM introduces an additional complexity with parametric equations for the dynamic optimisation of liquidity. CMMM, which incorporates metaprogramming and differential geometry, provides users with personalised liquidity algorithms. vAMM is a pioneer in the development of synthetic assets through primordial crittographic principles and sidechain technologies. These frameworks prioritise user accessibility, transparency and stability, with advanced functionalities such as governance integration and the mitigation of temporary losses.

Among those illustrated, the CPMM stabilises token prices by calculating the product of the x and y reserves within the liquidity pool, which remains a constant. This model, which is renowned for its user-friendly design, enables direct participation in decentralised finance trading. However, the CPMM doesn't come with no obstacles. It is important to consider the potential for arbitrage interventions, the susceptibility to market volatility and the risk of temporary losses. Despite these challenges, the CPMM's accessibility and simplicity have made it a fundamental element in the evolving DeFi landscape, significantly influencing the way users interact with decentralised exchanges.

6.4. Competition among DEX

In the course of time, the scientific literature has increasingly focused on aspects such as security, trading and arbitrage, analysing DEXs and the criticism related to them. A critical aspect that is frequently overlooked is the competitive mechanisms that govern the interactions within the DEX market. It is essential to pay attention to this aspect in order to understand the macroeconomic trends and drivers that will generate the competitive advantage that enables one to win the market. The advent of Web 3.0 has brought about a variety of changes to the drivers that have played a critical role in the acquisition of users and market share. The Web 3.0 is founded on the principles of decentralisation, data sovereignty, and interoperability, which enables the more equitable and secure distribution and management of data (Hassan et al., 2023). Indeed, there has been a transition from the centralised data management that is typical of the Web 2.0 era, in which giants such as Facebook and Google collect and monetise enormous quantities of user data. On the contrary, in the blockchain landscape, the absence of entry barriers and the open-source nature of applications have resulted in increased competition and volatility.

Uniswap, one of the most significant providers of financial infrastructure for the Web 3.0, has lost over 50% of its liquidity in a matter of days as a result of an attack known as a "vampire attack" orchestrated by SushiSwap. This attack was led by the pseudonymous founder Chef Nomi, who has forked the Uniswap code and launched SushiSwap. He is encouraging Uniswap liquidity providers to transfer their LP (Liquidity Provider) tokens to SushiSwap in exchange for SUSHI tokens. This process resulted in a rapid transfer of funds from Uniswap to SushiSwap, enabling SushiSwap to capture approximately 810 million dollars in tokens, or 55% of Uniswap's liquidity, in a matter of days (Staff, 2023).

Despite the initial negative impact, Uniswap has responded by launching its own governance token, UNI, in order to reactivate liquidity and reengage the community. This has resulted in a substantial recovery, with the total blocked value exceeding $3 billion in the subsequent months, demonstrating the protocol's adaptability and resilience.

This episode highlights the fact that there has been a growing competition among server providers. The paper by Zhang et al. (2022) examined the mechanism of "transaction fee mining" and how it played a critical role in market success. This mechanism involves the reimbursement of transaction fees to users in the form of governance tokens.

In particular, when users sell tokens on DEXs, they are required to pay a transaction fee, which typically amounts to 0.3% of the transaction volume. Then, DEX reimburses transaction fees to users in the form of governance tokens. The selection of payment options, combined with the quantity of given tokens, competes to fuel users' enthusiasm for participating in governance mechanisms, thereby increasing the value of tokens.

The transaction costs in DEX are primarily comprised of transaction commissions and transportation fees. The cost of token trading on DEXs is represented by transaction fees, while gas fees are the costs associated with the execution of smart contracts on the blockchain. These costs are subject to variation across different DEXs. It is evident that users incline to favour DEXs with lower transaction costs. The paper by Zhang et al. (2022) specifically discussed the fact that competition is based on two factors, namely the difference in transaction costs and the stickiness of consumers. Therefore, there is a dual perspective: one that is based on the actual cost difference between the various providers and another that is closely tied to the characteristics and behaviours of the client. It is demonstrated that, despite the fact that the provider of services with a lower transaction cost may be able to win the market, the users' satisfaction may offset this advantage. In addition, there is one final aspect to consider: incentive levels. With these, one refers to both the value and the quantity of governance tokens received. The mechanisms that contribute to the formation of the value of governance tokens are numerous and intricate to comprehend. The fundamental issue of this evaluation is still a topic that is not widely debated in the scientific literature. However, it is important to note that a higher level of incentive can generate virtues that increase the value of the tokens themselves and the demand from customers.

6.5. Challenges and Risks in DEX Security

A variety of criticisms have emerged in response to the popularity and widespread adoption of DEX. These latter incidents are typically exchange hacks, asset thefts and trust issues that significantly harm users and service providers' reputations. Numerous scientific studies have focused on the identification and mapping of the primary hacker attacks, with the aim of developing more effective models. The majority of attackers generate profits by integrating into automated sales mechanisms, which restrict customers from making purchases at higher prices.

In technical terminology, price slippage is defined as the change in the price of an asset between the start and conclusion of a trade. It is a parameter that should be considered when evaluating the reliability of a DEX. Indeed, there is a distinction between the expected price slippage, which is estimated based on the historical volume and frequency of transactions and the unexpected price slippage. This last term refers to the discrepancy between the actual trade price and the anticipated price. This variation may be due to unexpected causes, including hacker attacks. This phenomenon is complex to predict in advance, particularly in context with fluctuations in market liquidity and the number of trades conducted.

There are numerous trade-offs in terms of security with respect to DEX. In the actual world, the results of various strategies implemented to reduce the number of attacks have been contradictory. The DEX's attempt to increase transparency in relation to the operations and liquidity present is influenced in a certain way by the behaviours of the hackers. In fact, the fact that the prices of assets are determined in a completely automatic and predictable manner provides hackers with a certain level of knowledge, allowing them to execute their attacks with predictable outcomes. Furthermore, it is feasible to effectively participate in the transaction during its execution, as the price direction following the transaction will be predictable. Therefore, there is a trade-off between security and transparency, which on the one hand encourages decentralisation and on the other hand allows for a simpler method of information access by hackers. The paper written by Zhou et al. (2021) examined the impact of price slippage selection on the overall security of the DEX, beginning with the observation that an excessively low price slippage is always undesirable due to the increased likelihood of a transaction failing. Therefore, a price slippage that is excessively limited does not promote scalability, thereby restricting block transactions. On the other hand, a slippage that is excessively high allows malicious hackers to exploit the system.

Although there are numerous types of cyber attacks, the primary ones addressed in the literature are the front-running attack and the sandwich attack. Both utilise a structural characteristic of the blockchain, known as the Miner Extractable Value. This refers to the fact that order transactions are not executed immediately, but rather are left in a memory pool in anticipation of being executed. The order of priority with which they are executed is determined by the amount of gas fees that the user is willing to pay for the transaction, which are arranged in descending order. The mempool is publicly accessible and can be directly accessed through the node. In the front-running attack, as reported in Figure 6.1, the MEV-bot inserts a transaction of its own before the block transaction is executed, thereby modifying the selling price and capturing a profit from the unanticipated price slippage.

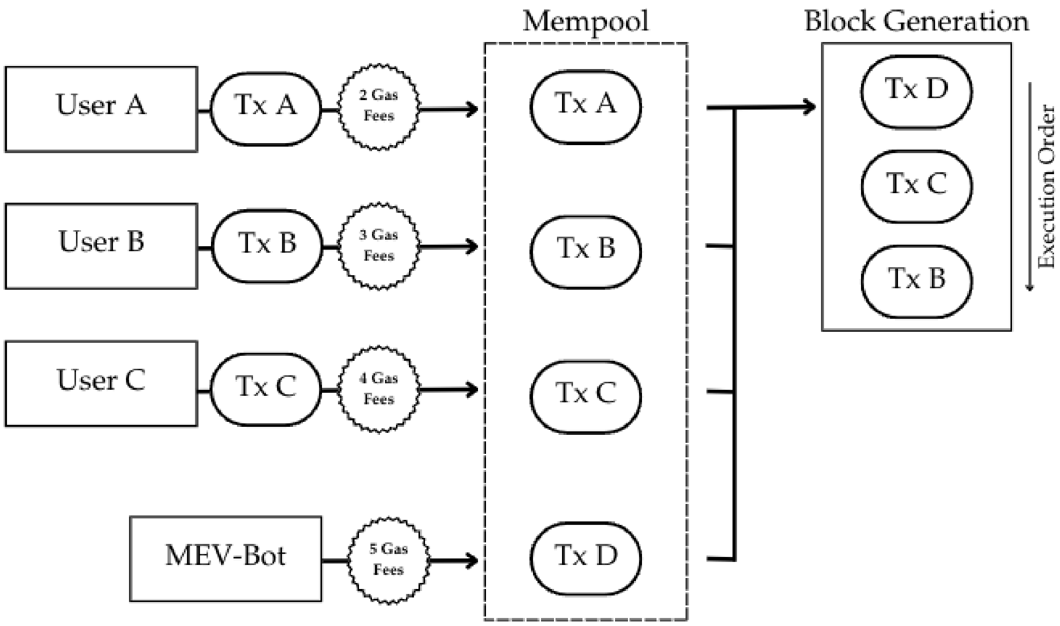


Figure 6.1: MEV transaction selection and frontrunning attack as described by Choi and Kim (2024)

In contrast, in a sandwich attack, as illustrated in Figure 6.2, the attacker places a front-running order to influence the asset's price and subsequently places a back-running order immediately after the victim's transaction. This procedure "splits" the victim's transaction between two attackers, maximising the attacker's profits from both the rise and fall of the asset price.

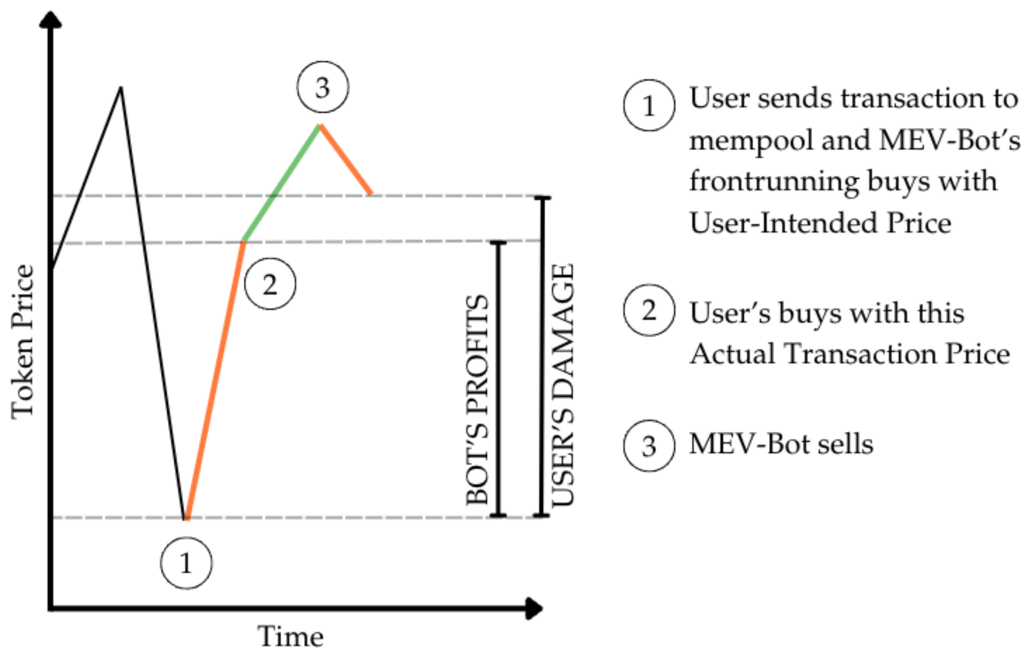


Figure 6.2: Execution process and profit generation section of sandwich attack as described by Choi and Kim (2024)

The bots may also benefit from some structural inefficiencies that characterise DEX. The price difference for the same assets, which is prevalent in various DEXs, enables bots to generate profits by utilising arbitration. Furthermore, in the majority of cases, the operations are not executed with the hacker's assets, but rather with an innovative leverage mechanism. Flash loans are an innovative form of credit that was introduced in decentralised finance. They allow users to borrow a specific amount of tokens from a liquidity pool, use them for a specific operation, and then recoup the loan amount and interest in a single transaction. This process occurs without the necessity of collateral or credit, a characteristic that distinguishes flash loans from traditional lending. The user obtains the desired token value from the liquidity pool and immediately employs it to execute a specific financial transaction, such as arbitrage between multiple exchanges. The key to a flash loan is that the entire process must be completed within a single blockchain transaction. If, for any reason, the user is unable to return the amount paid and the commissions within the same transaction, the entire transaction is invalid as if it never occurred. This mechanism ensures that the loan is always repaid, thereby eliminating the risk for the lender.

The paper by Choi and Kim (2024), which conducted a comprehensive study on the topics of bots and MEV, highlights the criticisms of these operations and how they negatively impact the trust of users, market mechanisms and transactions. Furthermore, it is demonstrated that hackers exploit market volatility and network congestion in a preponderant manner. This poses a significant threat to the scalability of DEX platforms. It is recommended to employ more dynamic security protocols and advanced monitoring systems to detect and respond positively to MEV attacks.

Another aspect that undermines the security of DEXs is the presence of token scams, which are illegitimate tokens that are created with the intention of tricking investors. These tokens are frequently presented with names that mimic those of legitimate tokens and promise high returns on investments without providing any real value or utility. The paper by Xia et al. (2021) argued that one of the causes of token scams is the lack of a structured regulation for token listing on exchanges and blockchains such as Ethereum do not regulate the denominator schemes of fraudulent tokens. Indeed, it is suggested that policies be developed to regulate the issuance of tokens on Ethereum and the list of liquidity pools on DEXs. In this instance, the dilemma of the trade-off between security and decentralisation is also revealed, which would be partially sacrificed in favour of a greater degree of control. However, the incorporation of a reputation system would be crucial, in conjunction with a greater level of investor awareness. These latter ones should rely on reliable sources such as CoinMarketCap or the official websites of DeFi projects to ensure that they are trading official tokens. Before investing in a liquidity pool, investors should carefully monitor the pool's transaction schedule and pay particular attention to currencies that experience rapid price increases in a short period.

6.6. DEX valuation

Having deeply analyzed how decentralized exchanges operate and the technologies they employ in the previous chapters, key parameters have been identified that can provide valuable insights into the overall value of these projects and their associated tokens. Drawing from both the analysis of valuation methods in Chapter 4 and a comprehensive assessment of DEX platforms, specific parameters have emerged as particularly relevant for conducting a relative valuation within the DEX ecosystem.

These parameters, shown in Table 5.3 with the area of interest they cover, systematically derived from an extensive examination of literature material, offer critical insights into the fundamental value drivers in the DEX space. While the parameters themselves will not be tested in this analysis, they remain a solid foundation for initial valuation due to their strong basis in existing literature. The systematic approach taken to identify these factors ensures that they are not only theoretically sound but also aligned with real-world applications and dynamics of decentralized exchanges.

To provide a comprehensive evaluation, the selected parameters will serve as a guideline for assessing DEX projects from multiple perspectives. In this follow section, the identified parameters will be presented along with detailed explanations for their inclusion, ensuring that a relative valuation framework is both rigorous and well-suited to the unique characteristics of DEX platforms.

Area of Interest	Parameter
User Activity	Daily Active Addresses
Liquidity	Total Value Locked
Transaction Security	Price Slippage
Revenue Generation	DEX Fees

Table 6.3: DEX Parameters and Areas of Interest

Daily Active Addresses This metric plays a similar role to the user engagement measurement discussed in Chapter 5 on Layer 2 systems. Unlike Layer 2 systems, where the focus may be on scalability and infrastructure, DEX platforms rely heavily on active user participation to facilitate liquidity and trading volume.

Therefore, Daily Active Addresses provides a clear picture of how many unique users are engaging with the exchange each day, by either initiating trades or providing liquidity. A higher number of active addresses indicates a greater level of user adoption and activity, which is crucial for maintaining the health and liquidity of the exchange. The Daily Active Addresses metric helps us better understand not just the number of unique users on the platform, but how engaged they are with trading activities, a core function of any DEX.

Total Value Locked It stands as one of the most important metrics for evaluating the performance and robustness of DEXs. TVL measures the total amount of digital assets locked in a platform's liquidity pools. A high TVL signals that a substantial amount of assets are committed to the platform, which is essential for the smooth functioning of its trading activities. This metric is critical because it reflects the overall participation and trust that users have in the platform.

Liquidity is closely tied to TVL, as it reflects a platform's ability to handle transactions effortlessly by providing enough assets to support trades. The higher the TVL, the more liquidity the platform has, making it easier for users to trade without delays or large price fluctuations.

Both Paper Şoiman et al. (2023) and Paper Metelski and Sobieraj (2022) recognized TVL as the most important metric for assessing the overall health of a DEX, as it influences not only the liquidity but also the platform's capacity to handle a diverse range of assets and trading volumes.

Price Slippage This is another critical metric when evaluating DEXs, as it directly impacts the security and reliability of trades on the platform. Slippage occurs when the final execution price of a transaction differs from the expected price due to liquidity constraints or rapid market fluctuations. Ensuring minimal slippage is crucial for the security and trustworthiness of a DEX, as excessive slippage can result in significant financial losses for users, particularly in volatile markets.

The formula for Price Slippage is typically expressed as:

$$\text{Slippage} = \frac{\text{Expected Price} - \text{Execution Price}}{\text{Expected Price}} \times 100$$

This metric measures the percentage difference between the price at which the trade was expected to be executed and the actual price at which it was finalized. A high slippage rate can be a red flag for traders, especially in platforms with low liquidity. In contrast, low slippage indicates a more secure and efficient trading environment, where users can execute trades at prices closer to their expectations.

Paper by Zhou et al. (2021) highlights that price slippage is a fundamental factor in determining the security of a decentralized exchange. By keeping slippage to a minimum, platforms can ensure that users are not exposed to unnecessary financial risks, thereby enhancing the overall trust in the network.

DEX Fees Fees play a central role in determining the revenue of DEXs. Most DEXs generate revenue by charging transaction fees on trades that occur within their platform. These fees are typically expressed as a small percentage of the transaction amount and are distributed to liquidity providers (LPs) who provide assets to liquidity pools, enabling trading. The exact amount of these fees and how they are distributed can vary depending on the specific DEX:

- Uniswap charges a 0.3% fee on each trade, with the entirety of the fee being distributed to LPs.
- SushiSwap divides its 0.3% fee between liquidity providers (0.25%) and the protocol's treasury (0.05%).

- PancakeSwap charges a 0.2% fee on Binance Smart Chain, distributing a portion to LPs while using the rest for the protocol's growth.

The amount of fees generated by a DEX depends largely on its trading volume and the size of its liquidity pools. Higher liquidity allows for more significant trades with minimal slippage, encouraging increased trading activity, which, in turn, generates more fees.

Fees are critical for evaluating the sustainability and long-term growth of a DEX. A robust fee mechanism ensures that liquidity providers are incentivized to continue supporting the platform. Moreover, the fee structure directly impacts the value of the DEX's token. Indeed, it is essential that the project maintains a steady revenue stream through trading fees, which can then be reinvested into the platform's development and incentivization mechanisms.

7 | Empirical Analysis

This chapter presents the empirical analysis conducted on a selection of Layer 2 blockchain projects, with the aim of evaluating their performance and value through a systematic approach. The analysis is structured into distinct sections, beginning with the introduction of the chosen L2 projects, followed by a detailed explanation of the data handling process and concluding with both a relative valuation model based on key parameters and a statistical analysis aimed at understanding the correlation between the selected parameters and the market capitalization of the chosen projects.

The first part introduces the L2 projects selected for this study. These projects have been chosen for their relevance in the blockchain space and their contributions to scalability solutions for Layer 1 blockchains. The focus is placed on understanding the unique characteristics of each L2 solution, such as their technological approaches (Optimistic Rollups, ZK-Rollups, Plasma Chain) and their impact on transaction speed, cost and network efficiency. By selecting diverse projects, this analysis aims to capture a range of L2 strategies that enhance Ethereum's scalability and transaction throughput.

In the next section, the data sources are outlined, specifying where the relevant data for the selected L2 projects was obtained. This includes both on-chain and off-chain metrics such as transaction speed, daily active addresses, gas fees and L1 price correlations. The data was sourced from reputable platforms such as Etherscan and other blockchain analytics tools.

A relative valuation approach was applied using financial multiples, with a particular emphasis on the Market Capitalization/Daily Transactions ratio as the primary metric. Daily Transactions was chosen as the key parameter, following a systematic review of Layer 2 solutions, which highlighted its strong correlation with platform success. Given that the primary objective of L2 solutions is to enhance the scalability of Layer 1 networks by increasing transaction throughput, this metric provides a clear reflection of platform performance. Additionally, Total Value Locked was used as a companion variable, enabling a more accurate linear regression analysis across the multiples of each project. This comprehensive approach will contribute to a deeper understanding of the potential and performance of L2 solutions in the blockchain ecosystem.

7.1. Introduction to Selected L2 Projects

As discussed extensively in the dedicated chapter, Layer 2 projects arise with the goal of improving the scalability of Layer 1 networks, particularly by reducing transaction costs and increasing the speed of operations.

In order to provide quantitative results, four L2 projects were selected: Optimism, Mantle, Arbitrum and Polygon. This choice was made to ensure consistency of information in order to conduct an accurate comparative evaluation. Indeed, all of these projects were developed on Ethereum's L1 network. It is important to note that, both as a matter of data availability and as a matter of sample reliability, projects with a market capitalization above 500 million euros were chosen.

Optimism Optimism is an L2 solution built on Etherium launched in 2021. It uses Optimistic rollups technology to increase main-chain scalability. It is one of the most successful L2 projects, launched its OP token in 2022 via two "airdrops" and has a market capitalization as of September 9, 2024 of 1.56 billion euros.

An airdrop is a strategy used by Blockchain projects to distribute a certain amount of tokens to a community of users for free. Airdrops can be targeted at users who already own a specific cryptocurrency or have participated in a specific activity, such as signing up for a newsletter, following the project on social media, or using a platform. The main goal of an airdrop is to increase the visibility of the project, create an initial user base, and stimulate interest and adoption of the launched token.

OP is primarily a governance token, so it gives holders the rights to participate in "the optimism collective," which is a governance system articulated on two "bodies": the Token House and the Citizens' House. The former has decision-making power over technical Optimism issues while the latter has decision-making power over issues related to the financing of public goods. Public goods are all the resources that can potentially bring value to the project community.

Arbitrum As well as Optimism, Arbitrum has been very successful in the area of L2 solutions developed on Ethereum. One of Arbitrum's strengths is its compatibility with the Etherium Virtual Machine, which allows developers to be able to integrate existing dApps on the L1 without having to make code changes. The EVM, in fact, is Ethereum's decentralized virtual environment in which smart contracts run. The EVM operates on thousands of computers participating in the Ethereum network; this distribution across nodes ensures the security and reliability of the network.

The Arbitrum project was officially launched in 2018. In March 2023, the Arbitrum token (ARB) was launched via an airdrop aimed at early users and supporters of the network. ARB, as well as OP, is predominantly a governance token that allows holders to propose changes to the Arbitrum ecosystem. In addition, those who hold ARB tokens can choose members of an internal Arbitrum security council, called the "Arbitrum security council." Arbitrum to try to improve Ethereum's scalability relies on Optimistic Rollups technology. ARB as of September 9, 2024 shows a capitalization of about 1.63 billion euros and is one of the L2 projects with the highest capitalization.

Mantle Mantle is an L2 scalability solution that uses Optimistic rollups. Transactions are then executed off-chain and finally settled and recorded on-chain. Mantle features a modular design: instead of executing key Blockchain functions on a single layer, it manages them on different layers. In fact, a modular blockchain aims to handle the 4 core functions of the blockchain separately: data availability, consensus, execution, and settlement. Mantle in particular, uses optimistic rollups and a separate data availability layer. Although it is not the only L2 solution characterized by this structure, Mantle succeeds in achieving hypescalability, namely it succeeds in achieving higher transaction speeds and lower fees costs, due to its decentralized data availability layer (EigenDA), compared to other L2 solutions. EigenDA is a decentralized protocol that allows security to be managed at the data availability layer directly through Ethereum. Typically, however, other L2 solutions use a separate centralized data availability layer. This is the main difference that distinguishes Mantle from other L2 projects.

In May 2023, Mantle integrated with BitDAO, creating a single ecosystem and a single reference token (MNT). BitDAO (BIT), was the token launched by DEX Bybit. MNT can be classified as both a utility token and a governance token. In fact, MNT gives the holders decision-making rights over the Mantle protocol and at the same time must be used to pay transaction execution fees. Mantle as of September 9, 2024, has a market capitalization of about 1.63 billion euros.

Polygon Polygon, formerly named as Matic Network, is a solution that combines the technologies of ZK-rollups, Optimistic rollups and sidechains to improve the scalability of Ethereum created in 2017 in India. Polygon uses a PoS consensus algorithm to validate transactions and ensure security. Most sidechains used by Polygon to execute transactions and increase network scalability are EVM-compatible; the main sidechain is named

PolygonPos.

Polygon has been very successful, including in the media, because it is called "carbon neutral." Indeed, as we have already discussed, operations that take place on the Blockchain involve high energy consumption. Polygon seeks to balance the high carbon emission generated by the operations carried out on its Blockchain by purchasing so-called "carbon credits".

Carbon credits are financial instruments used to represent the reduction of one ton of carbon dioxide or another equivalent greenhouse gas. Polygon, working with specialized sustainability entities, has committed to participate, through the acquisition of these carbon credits issued by such projects, in activities that reduce carbon emissions such as reforestation, adoption of renewable energy, and carbon capture and sequestration. For these reasons, Polygon is considered one of the most sustainable Blockchain projects in the cryptocurrency market.

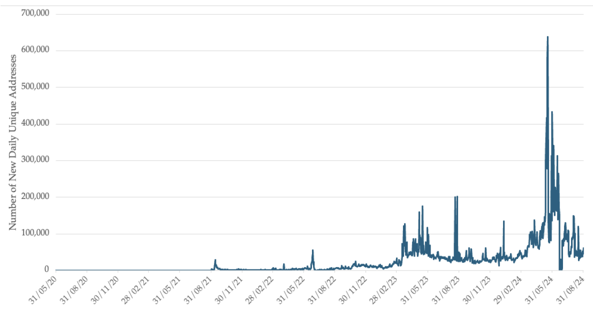
Polygon's official token is MATIC. Again, MATIC allows holders to be able to perform multiple functions. MATIC is an ERC-20 token and can be considered both a utility and governance token. Specifically, in addition to giving holders the right to participate in organizational matters of the Polygon protocol, it is used by users both to pay fees on the network and as collateral, and consequently delivered in the form of rewards, in the staking process. In early September 2024, the Matic token changed its name to POL. As September 9, 2024, Polygon, with a capitalization of €3.5 billion euros (Considering both MATIC, that is still in circulation, and POL), is the most highly capitalized L2 project.

7.2. Data Collection and Preparation

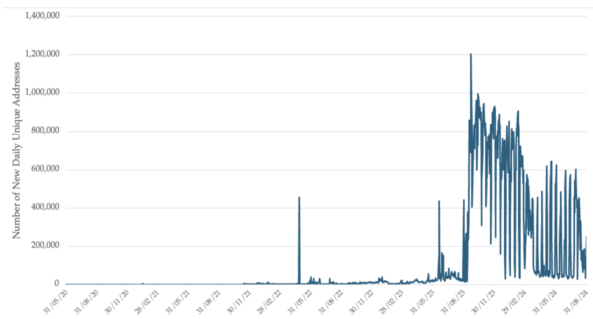
The data used for the empirical analysis of Layer 2 projects were extracted from various blockchain explorers that are specialized for each L2 solution. These explorers, which are derived from Etherscan, offer detailed insights into the activity of specific L2 networks. For each selected L2 project, data on key metrics such as daily unique addresses, TPS and daily gas fees were retrieved from the appropriate explorers. To extract the gas fees for Arbitrum, Dune[1] was used, as the data on Arbiscan calculated gas fees based on a actual gas price rather than the effective gas price. Dune provided a more accurate representation of the real transaction costs on the network. In particular, the data was extracted from Dune using SQL queries.

[1]https://dune.com/home

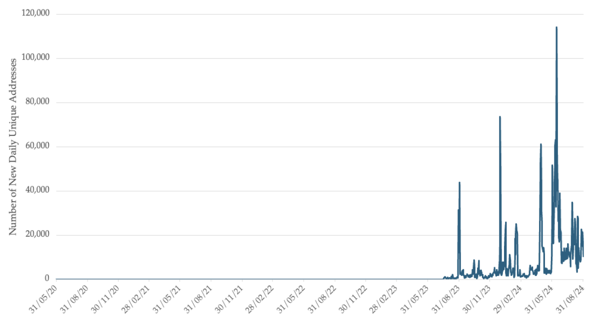
This data was gathered from specific explorers such as Arbiscan[2] for Arbitrum, OP Mainnet Explorer[3] for Optimism, Mantle Mainnet Explorer[4] for Mantle and Polygonscan[5] for Polygon.



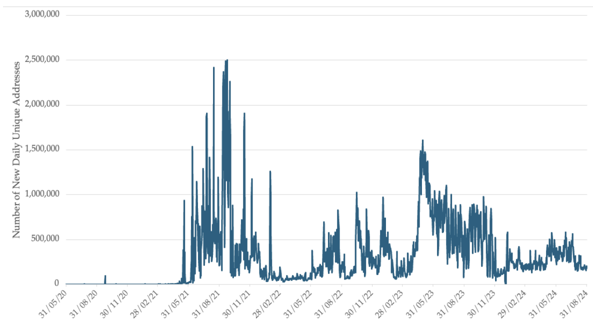
(a) Arbitrum



(b) Optimism



(c) Mantle

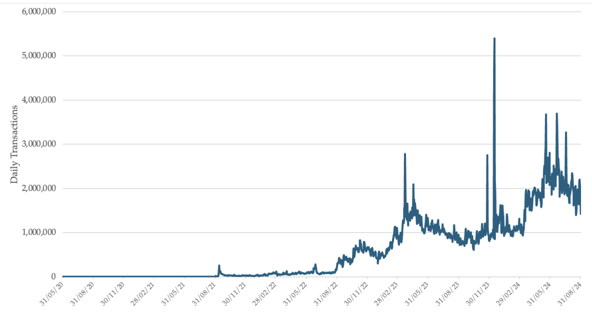


(d) Polygon

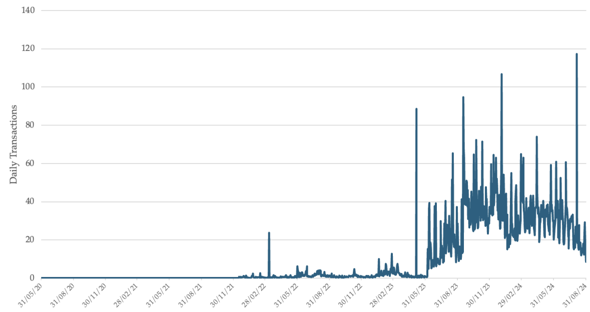
Figure 7.1: Number of New Daily Unique Addresses from 31/05/2020 to 31/08/2024

These explorers track the number of new unique addresses that interact with the network each day. This metric is presented in Figure 7.1, where the daily number of unique addresses for each L2 project is visualized, allowing for a comparative analysis of user engagement across projects.

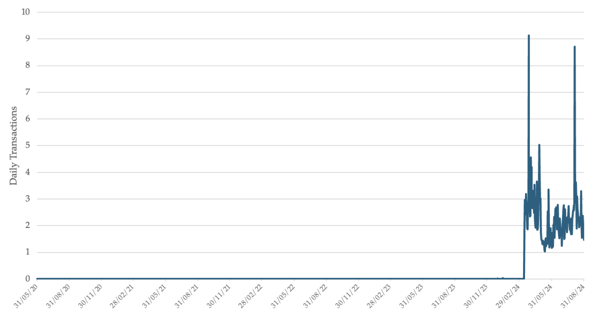
[2] https://arbiscan.io
[3] https://optimistic.etherscan.io
[4] https://explorer.mantle.xyz/
[5] https://polygonscan.com/



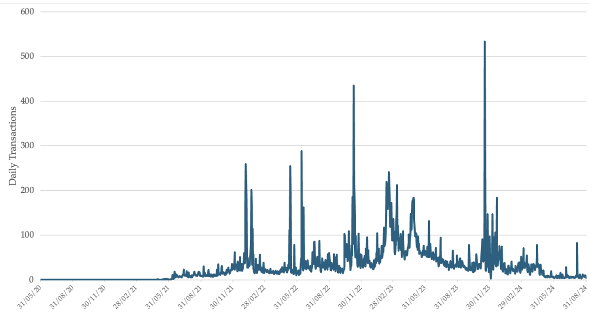
(a) Arbitrum



(b) Optimism



(c) Mantle

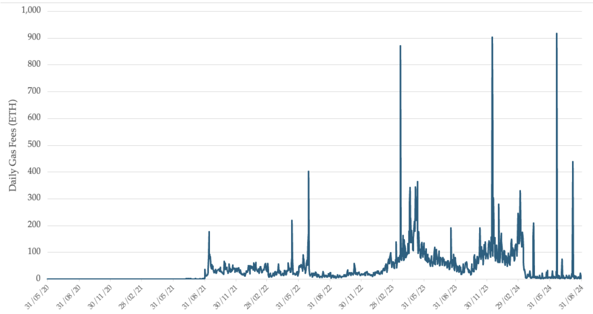


(d) Polygon

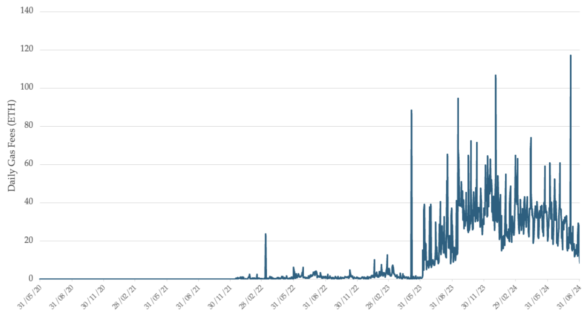
Figure 7.2: Number of Daily Transactions from 31/05/2020 to 31/08/2024

Instead of focusing on TPS, this analysis maintains the metric in terms of daily transactions (TPD). Indeed, the choice to keep the analysis on a daily basis was made due to data availability and to ensure that throughput metrics align with daily price fluctuations and other critical variables. This data is shown in Figure 7.2, where the daily transaction volumes are visualized for each project.

Daily gas fees represent the transaction costs incurred by users on L2 networks. This metric was derived from the data available on the scanner and explorer, as described in the gas fee formula. This metric helps evaluate the cost-effectiveness of each L2 solution and is presented in Figure 7.3 to allow for comparison between projects. By examining gas fees in relation to other parameters such as price, it possible derive insights into the Price/Cost efficiency of each L2 project. To ensure data consistency, all gas fees were converted to ETH, as some projects originally used their native tokens as the unit of measurement for transaction fees. This approach standardizes the fees across different projects, allowing for a more accurate comparison and analysis.

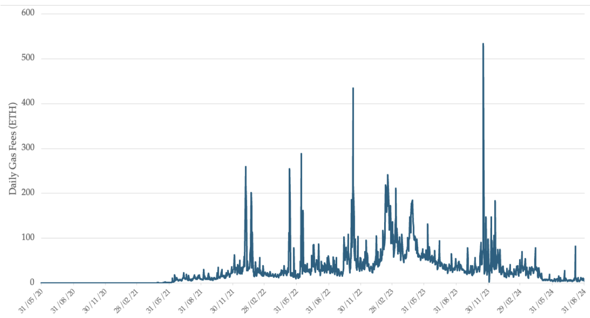


(a) Arbitrum



(b) Optimism

(c) Mantle



(d) Polygon

Figure 7.3: Number of Daily Gas Fee (ETH) from 31/05/2020 to 31/08/2024

Finally, the price of Ethereum was sourced from CoinMarketCap [6] for the analysis. This is because all the Layer 2 projects under consideration are built on Ethereum as their Layer 1 foundation. This metric helps assess how dependent L2 projects are on the price movements of their underlying L1 networks.

It's important to emphasize that data collection began from the launch date of each project's token, as this is necessary to correlate the metrics with market capitalization. Without the token launch, market capitalization cannot be calculated, making it essential to focus on data post-launch. This approach is also crucial for the next step of the relative valuation, where the selected metrics will be correlated with market capitalization to provide more meaningful insights. Data were gathered up until September 3, 2024, with a focus on how each project's parameters correlate with their token values, rather than requiring uniform starting points for all datasets. As a result, the variation in the timing of data initialization does not compromise the validity of the empirical analysis, at least up to this stage.

[6] https://coinmarketcap.com/

7.3. Relative Valuation Using Multiples

The next step involves conducting a relative valuation. This method allows us to compare projects based on a key performance metric, offering a clearer understanding of their positioning. As previously mentioned, the Daily Transactions parameter was selected because it reflects the primary goal of Layer 2 solutions: increasing the network scabalabilty by raising the number of transactions processed.

For these reasons, it was decided to use **Market Capitalization / Daily Transactions (MC/TPD)** as a multiple in conducting a relative valuation.

To further enrich the analysis, Total Value Locked was selected as a companion variable, as suggested by Damodaran (2002). TVL refers to the total value of assets locked within a Layer 2 system, representing the trust and capital users are willing to commit to the network. A higher TVL generally reflects greater network adoption and a larger user base, which can justify a higher valuation. By combining MC/TPD with TVL, the objective is to perform a linear regression between the multiples of the various projects and their respective TVL. This approach aims to identify an equation that allows us to determine the correct multiple associated with the corresponding TVL of the specific Layer 2 project being analyzed.

Figure 7.4 reports MC/TPD trends for each L2 from 17/08/2024 to 31/08/2024.

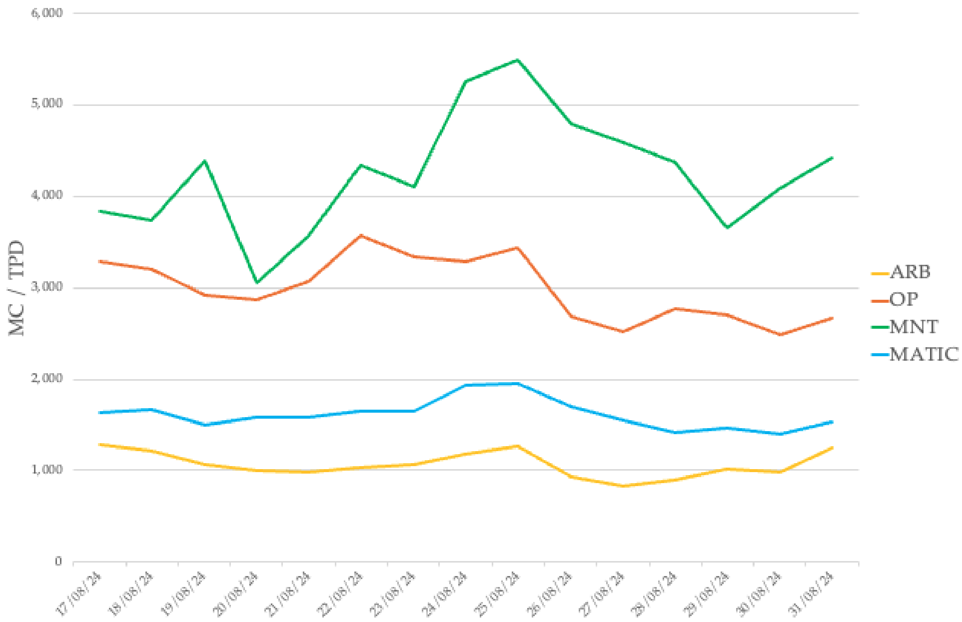


Figure 7.4: MC/TPD from 17/08/2024 to 31/08/2024

For this primary analysis, the focus was specifically on the period of maximum market downturn during the last two weeks of August 2024 (from 17/08/2024 to 31/08/2024). Choosing data from moments of market decline allows us to better assess the resilience and fundamental strength of each project. During downturns, the multiples for highly speculative projects tend to contract and align more closely with their true operational performance, allowing for a more accurate comparison of Layer 2 projects. Using 20/08/2024 as the reference day, a linear regression between multiples MC/TPD and TVL values was performed.

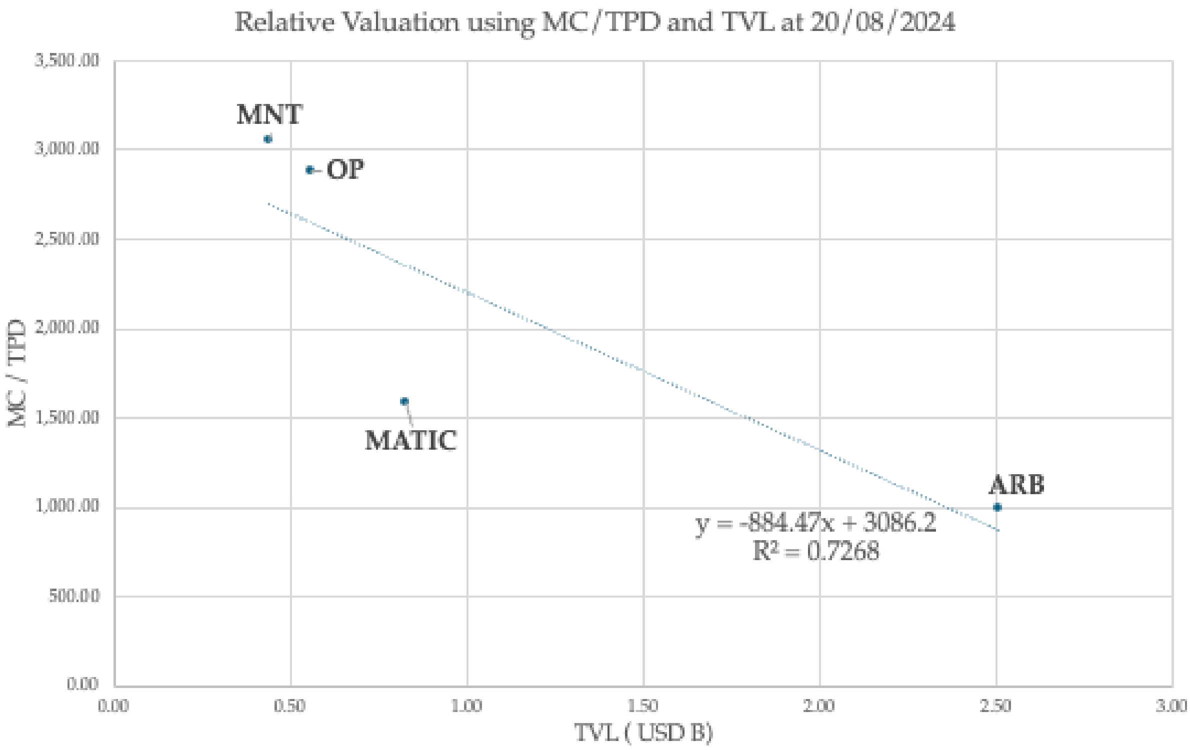


Figure 7.5: Relative Valuation

As shown in Graph 7.5, the correlation between MC/TPD of each project and TVL yielded an R^2 of 0.72, which is fairly significant. This indicates that approximately 72% of the variance in Market Capitalization per Daily Transaction can be explained by differences in Total Value Locked across Layer 2 projects. This result underscores the importance of TVL in evaluating the underlying value of L2 networks and provides further confirmation that daily transactions and TVL are notable drivers in determining the valuation of Layer 2 tokens.

Subsequently, the analysis was further expanded. In the final phase, daily market capitalization and transaction data were gathered for all projects over the past three months

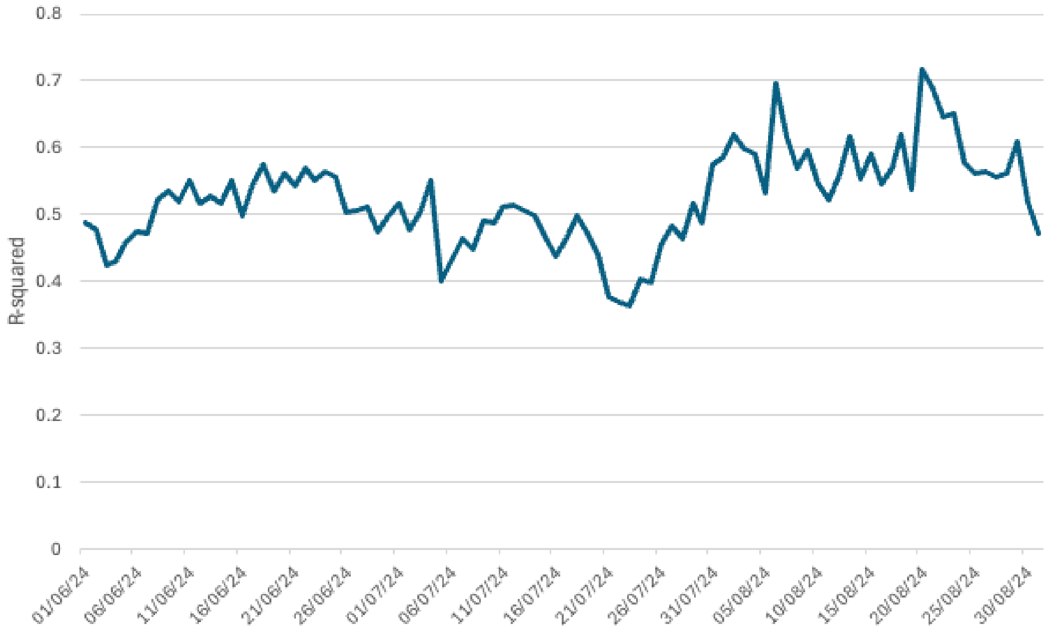


Figure 7.6: R-squared in June, July and August 2024

(June, July and August 2024). MC/TPD multiples were calculated for each day for every project throughout the entire three-month period.

The results showed that this process consistently resulted in equations with a negative slope and a positive intercept. Additionally, an average R^2 value of 0.52 was found over the entire period (Figure 7.6).

While this R^2 value is not particularly high, it represents a satisfactory outcome for the three months analyzed, indicating a certain level of robustness and consistency in the model. However, several factors, such as external influences like sudden changes in the price of ETH, contributed to distorting the data and inevitably affecting the results. These uncontrollable variables introduced fluctuations that impacted the model's accuracy, but they do not undermine its overall validity.

This approach allows us to conduct a more consistent and reliable comparison across different Layer 2 projects, helping identify potential opportunities for investment based on both transaction activity and network efficiency.

7.4. Statistical Analysis

In this section, the analysis focuses on the results of SARIMAX models applied to the tokens Arbitrum (ARB), Optimism (OP), Mantle (MNT) and Polygon (MATIC). The objective of this analysis is to evaluate the relationships between key variables such as the number of daily transactions, gas fees (in ETH), new daily active addresses, the value of Ethereum (in USD) and their respective impacts on token market capitalization. By exploring these relationships, the goal is to identify the most influential parameters driving market capitalization movements, offering insights into the dynamics of each market.

The decision was made to analyze the correlation of these parameters with market capitalization rather than token price, as the price is highly volatile and strongly influenced by token supply. Indeed, several of the selected projects, during the period analyzed, released large amounts of tokens through airdrops. For example, Arbitrum distributed a significant number of tokens via airdrops from March 2024 to September 2024. This had a substantial impact on the token price, as the sudden increase in supply can significantly depress its value. Therefore, market capitalization provides a more stable and reliable measure for comparison.

Before conducting the regression analysis, a Variance Inflation Factor analysis was performed. The VIF analysis is critical for detecting multicollinearity, which occurs when independent variables are highly correlated. High multicollinearity can distort the regression model, leading to unreliable coefficient estimates and inflated standard errors, making it difficult to determine the individual effect of each variable on the dependent variable (market capitalization). By conducting the VIF analysis, the study ensures that the regression model is robust and free from multicollinearity, allowing for a clearer interpretation of the results. An intercept (labeled "const" in the tables) was included to create a more accurate and realistic model. This allows the regression line to better fit the data by accounting for the baseline value of the dependent variable when all independent variables are zero, ultimately improving the model's predictive accuracy and interpretation.

Feature	ARB VIF	OP VIF	MNT VIF	MATIC VIF
const	15.4797	10.3749	18.3730	5.5134
Daily Transactions	2.0924	1.6782	1.4335	1.8362
Daily Gas Fee (ETH)	1.1134	2.2411	1.7343	1.1156
New Daily Unique Addresses	1.5284	1.5272	1.4481	1.1282
ETH Value (USD)	1.7662	1.8650	1.6726	1.6598

Table 7.1: Variance Inflation Factor (VIF) for ARB, OP, MNT, and MATIC

The results of the VIF analysis, shown in Table 7.1, indicated that the independent variables did not exhibit significant multicollinearity, as all VIF values were within acceptable thresholds of 5 (Yoo et al., 2014). This finding confirms that the selected variables are sufficiently independent of one another, ensuring that the subsequent regression estimates are reliable.

Regarding SARIMAX, the p-value is the most significant parameter in this analysis, as a value below 0.05 indicates a statistically significant impact between the variable in question and the market capitalization.

	ARB	OP	MNT	MATIC
Daily Transactions	0.237	0.003	0.275	0.099
Daily Gas Fee (ETH)	0.035	0.214	0.000	0.875
New Daily Unique	0.985	0.578	0.797	0.822
ETH Value (USD)	0.000	0.000	0.000	0.000

Table 7.2: Comparison of p-value Across Different L2 and Metrics

Specifically, for Arbitrum, as shown in Table 7.2, both Daily Gas Fees and Ethereum price have a statistically significant impact on the Market Capitalization. Notably, the Daily Gas Fees exhibit a negative coefficient, meaning that as the Gas Fees increases, Market Capitalization decrease. In contrast, the ETH price has a positive coefficient, indicating that both variables move in the same direction.

For MATIC, only the ETH price exhibits a statistically significant impact, with a positive coefficient.

In the case of Mantle, both Gas Fees and ETH price are statistically significant and have positive coefficients, indicating that they both increase with Market Capitalization. Similarly, for Optimism, both Daily Transactions and ETH price exhibit positive coefficients, and their p-values fall below the threshold, affirming their statistical significance.

This consistent pattern across all projects highlights that the ETH price consistently has a statistically significant impact on Market Capitalization, reinforced by both the positive coefficients and the low p-values.

To address the remaining volatility in the residulas, a GARCH model was applied. Basically, according to this model, three key parameters are estimated: omega, alpha, and beta.

- **Omega**: represents the long-term average variance, or the constant component of volatility. It reflects the baseline level of volatility that is always present, regardless of recent market fluctuations.
- **Alpha**: measures the impact of recent shocks or innovations on current volatility.

A higher alpha indicates that recent events (such as sudden price changes) have a stronger influence on volatility.

- **Beta**: captures the persistence of volatility over time, meaning how much past volatility affects future volatility. Higher beta values indicate that volatility tends to cluster or remain elevated after a large market move.

In the current analysis, all projects except for Optimism showed a statistically significant impact only on the omega parameter, meaning that for these projects, the baseline level of volatility is the most significant driver of Market Capitalization variance. However, for OP, the alpha parameter was statistically significant, indicating that recent price shocks have a stronger influence on its volatility compared to other projects.

Overall, this chapter has established a clearer understanding of the dynamics affecting Layer 2 projects, particularly the significant role of Ethereum's price and the varying impact of project-specific variables. These insights provide a foundation for further analysis and more refined valuation models.

8 | Conclusions and future developments

Through an extensive review of the literature on token taxonomy and valuation, this thesis successfully addressed the gaps identified in both the taxonomy and valuation domains. A systematic examination of the taxonomy literature revealed key points of convergence across various existing frameworks. These shared characteristics were analyzed and summarized, providing a comprehensive overview of the current taxonomy landscape. Among the reviewed works, the study by Alzhrani et al. (2022) stands out for its thoroughness and precision regarding the dimensions and attributes discussed.

The results from the taxonomy review highlighted several core characteristics that consistently emerged across the majority of analyzed papers. These findings underscored the complex nature of distributed ledger technology systems and tokens, with a stronger emphasis placed on the systems themselves rather than the tokens. It became clear that while token characteristics remain relatively stable within a given DLT system, the system itself plays a crucial role in shaping token behavior. The token landscape is converging toward three primary types: Security Tokens, Utility Tokens, and Payment Tokens. However, the fragmented regulatory landscape across different jurisdictions adds complexity to token classification, particularly regarding the legal and accounting treatment of these assets.

After completing the taxonomy review, the focus shifted to valuation methodologies. A systematic review of the literature, combined with an analysis of grey literature, revealed a significant lack of structured valuation models, especially for DeFi tokens. While structured valuation approaches, often centered on revenue-based metrics like Price-to-Earnings ratios, have emerged for cryptocurrencies, DeFi tokens, which frequently serve governance or utility functions within decentralized ecosystems, present unique challenges. To address this gap, a relative valuation model was developed based on parameters identified from the academic material. In particular, a systematic review of the literature on Layer 2 and decentralized exchange landscapes enabled the identification of distinct parameters for these types of projects. For L2s, four key drivers were identified: Transactions per Day, Daily Gas Fees, Number of New Unique Addresses and correlation with the price of the associated L1 Blockchain. For DEXs, the drivers identified were: Daily Active Addresses, Price Slippage, Total Value Locked and DEX Fees.

The next step was to apply the relative valuation methodology. Given the strong relevance of daily transactions in L2 landscape, Market Capitalization per Daily Transactions (MC/TPD) was selected as the primary valuation multiple for comparing the performance of different projects. After selecting a specific day for the calculations, the MC/TPD multiple was computed for each project. To derive a standardized multiple, as suggested by Damodaran (2002), Total Value Locked was chosen as an companion variable, reflecting the level of user trust and capital committed to each L2 network.

This analysis revealed varying trends in the MC/TPD multiple across projects. However, regression analysis between each project's multiple and TVL values demonstrated a strong correlation, with an R^2 of 0.72. This suggests that a significant portion of the variance in Market Cap per Transaction can be explained by differences in TVL, indicating that both daily transaction activity and the amount of assets locked within a network are key drivers in determining the valuation of L2 tokens.

The analysis was expanded by collecting daily market capitalization and transaction data for various projects over June, July, and August 2024. MC/TPD multiples were calculated for each day. The results consistently showed a negative slope and positive intercept in the resulting equations, with an average R^2 value of 0.52%. It indicates moderate robustness in the model over the period. External factors, such as sudden changes in ETH prices, introduced fluctuations that impacted the model's accuracy but did not invalidate its overall conclusions.

This final finding could provide valuable insights for assessing the token value of new L2 projects by using the multiples derived from the regression analysis of MC/TPD and TVL.

After Relative Valuation, a SARIMAX was conducted to assess and test the influence of these parameters on each token's market capitalization (MC). The aim was to identify which variables had the strongest correlation with the MC of the L2 projects.

The analysis using SARIMAX models has provided valuable insights into the key factors influencing the market capitalization of Layer 2 tokens. The findings highlight that the price of Ethereum consistently exhibits a statistically significant impact on the market capitalization of all projects, with various other parameters like gas fees and daily transactions showing differing levels of influence across specific projects. The decision to focus on market capitalization rather than token price proved effective, as it provided a more stable basis for comparison, particularly in light of external factors such as token airdrops.

Furthermore, the application of a GARCH model addressed the residual volatility in the data, revealing that for most projects, the baseline level of volatility (omega) was the primary driver of market capitalization variance, while Optimism's volatility was more strongly influenced by recent price shocks (alpha).

While the relative valuation model proposed in this thesis provides valuable insights into the valuation of Layer 2 tokens, there are several limitations that need to be acknowledged. First, the model heavily relies on a small number of specific variables (Transactions per Day), which may not capture the full complexity of the factors influencing token prices. This creates a potential oversimplification, as other important variables such as network decentralization, governance mechanisms and protocol upgrades are not considered. Additionally, the model's dependency on historical data can limit its predictive power in rapidly evolving markets, where new technologies or regulatory changes can quickly alter market dynamics. Another limitation is the reliance on Ethereum as the common Layer 1 blockchain for the selected Layer 2 projects. While Ethereum is the dominant platform, other Layer 1 chains like Solana or Avalanche might display different correlations and valuation drivers. Furthermore, the analysis is based on only four tokens over a limited time period, which could restrict the model's generalizability and robustness across different market conditions. These limitations suggest that while the relative valuation model is a useful tool, it should be applied with caution and complemented by additional qualitative and quantitative analyses for a more comprehensive valuation approach.

Looking ahead, future developments could focus on creating a unified and comprehensive taxonomy that provides a well structured framework for the classification of DLT systems and tokens. The current fragmented nature of token classifications, influenced by varying regulatory and technological approaches, calls for a more standardized system that can adapt to the rapidly evolving blockchain landscape. This would not only offer clarity for industry stakeholders but also facilitate regulatory compliance, enhance market transparency, and provide investors with clearer insights into the nature of the digital assets they engage with. Such a taxonomy would need to be flexible enough to accommodate new innovations, such as hybrid tokens or emerging blockchain models, while maintaining enough structure to provide a consistent framework for evaluation and classification.

Moreover, it would be valuable to extend the research to analyze emerging blockchain projects. These new projects often bring innovative technologies, governance models, and token dynamics that could challenge the parameters and valuation models currently in use. By incorporating data from these newer projects, researchers could further refine the relative valuation models developed in this thesis, ensuring that the models remain relevant and robust in the face of ongoing innovation. Analyzing these projects could also highlight new valuation drivers or metrics that have not yet been considered, such as the impact of decentralized governance participation.

Finally, extending the research to include long term metrics such as the health and sustainability of blockchain ecosystems, governance activity, and decentralization levels, could offer more comprehensive insights into the factors driving token value. These metrics could provide a better understanding of how community engagement, network security, and governance participation influence the perceived value of a project, especially in the long run. Ultimately, these developments could contribute to creating more accurate and adaptable valuation frameworks, enhancing both academic understanding and practical applications in the field of blockchain and digital asset evaluation.

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List of Symbols

World	**Symbol**
BitDAO	BIT
Data Availability Layer	DA
Mean Absolute Error	MAE
Anti money Laundering	AML
Arbitrum	ARB
Automated Market Makers	AMMs
Bitcoin	BTC
Centralized exchanges	CEXs
Decentralized application	dApp
Decentralized Exchange	DEX
Decentralized Finance	DeFi
Delegated Proof of Stake	DPoS
Directed Acyclic Graph	DAG
Discount Cash Flow	DCF
Discussion Paper	DPoS
Distributed Ledger Technology	DLT
Double Spending	DS
Ethereum	ETH
Ethereum Virtual Machine	EVM
Fungible Token	FT
Generally Accepted Accounting Principles	GAAP
Gross Merchandise Volume	GMV
Initial Coin Offering	ICO
Initial Exchange Offering	IEO
Initial Public Offering	IPO
International Financial Reporting Standards	IFRS
Internet of Things	IoT

Know Your Customer	KYC
Knowledge Rollup	KR
Layer 0	L0
Layer 1	L1
Layer 2	L2
Liquidity Providers	LP
Mantle	MNT
Market Capitalization/Daily Transactions	MC/TPD
Markets in Crypto-Assets	MiCA
Maximal Extractable Value	MEV
Mean Squared Error	MSE
Net Value of Transactions	NVT
Network Value to Fee Revenue ratio	NVF
Network Value to Transactions/Growth	NVTG
Nominated Proof-of-Stake	NPoS
Non Fungible Token	NFT
Optimism	OP
Polygon	MATIC and POL
Price-Earnings/Growth	PEG
Price-to-Earnings	PE
Price-to-Metcalfe ratio	PM
Price-Utility ratio	PU
Proof of Authority	PoA
Proof of Stake	PoS
Proof of Work	PoW
R-squared	R^2
Root Mean Squared Error	RMSE
Reporting Advisory Group	EFRAG
Security Token Offering	STO
Small and Medium Enterprises	SMEs
SushiSwap	SUSHI
Total Value Locked	TVL
Transactions per day	TPD
Transactions per second	TPS

Uniswap	UNI
Variance Inflation Factor	VIF