POLITECNICO DI TORINO

Master's Degree Course in Management Engineering

Master's Thesis

The Tokenization of Assets: Analysing the Emergence of a New Market Trend.

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“Vires in numeris”.

Anonymous.

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ABSTRACT

This thesis explores the rapidly emerging trend of asset tokenization, which is reshaping how assets are owned, traded, and managed across various industries. Tokenization transforms physical assets into blockchain-based digital tokens, making them easier to trade, more liquid, and accessible to a broader range of investors.

The study begins with an historical overview, illustrating the evolution of tokenization from traditional financial instruments to the development of blockchain technology. It then provides a technical explanation of how different blockchains works and could be used to tokenizes Real Word Assets (RWA). Then a detailed market analysis will be presented, examining the most impacted industries by tokenization, such as real estate, art, commodities, and financial instrument.

Furthermore, some use case will be discussed, with a focus on successful projects within each sector. Finally, a theoretical model for the tokenization of Credit Default Swaps is introduced, laying the groundwork for future research in this unexplored area.

Introduction to Tokenization of Assets

1.1 Overview of Tokenization

Tokenization is a transformative process that converts rights to an asset into a digital token on a blockchain [1]. This innovative approach allows assets, both tangible like real estate and intangible like intellectual property, to be digitally represented and transacted with greater efficiency and security. Since the advent of blockchain technology, tokenization has expanded beyond cryptocurrencies, promising to revolutionize traditional asset management by enhancing liquidity, reducing transaction costs, and increasing transparency.

The significance of tokenization is not merely technological but also deeply economic, affecting how assets are bought, sold, and managed across borders. It represents a shift towards a more democratized and accessible market, where smaller investors can participate in asset classes previously accessible only to large investors or specialized professionals.

1.2 Historical Context and Evolution

The journey towards asset tokenization began with the evolution of financial instruments and digital technology. Initially, asset management was manual, involving cumbersome processes that limited accessibility and liquidity. The late 20th century witnessed a digital revolution that transformed all sectors, including finance. The introduction of electronic trading platforms in the 1970s, such as NASDAQ, marked the beginning of the digitization of financial markets. These platforms enabled faster and more efficient trading of securities, which were increasingly represented digitally rather than as physical certificates. This shift laid the groundwork for complex financial instruments and derivatives that characterize modern financial markets.

The pivotal breakthrough in the narrative of tokenization came with the development of blockchain technology in 2008, introduced by the pseudonymous entity Satoshi Nakamoto with the release of the Bitcoin whitepaper. Blockchain technology offered a decentralized and secure platform for digital transactions without the need for a central authority, providing

an immutable record of ownership and transactions. The success of Bitcoin [2] demonstrated the potential of using a Distributed Ledger Technology (DLT) for financial transactions, paving the way for more complex applications.

The introduction of Ethereum [3] in 2015 expanded the concept of tokenization to a wider range of assets beyond financial instruments with smart contracts. This innovation allowed for the creation of decentralized applications [4] (dApps) that led to the development of complex financial interactions on the blockchain, such as decentralized finance [5] (DeFi) and non-fungible tokens [6] (NFTs), further broadening the scope and utility of tokenized assets.

As the technology matured, various sectors began exploring the benefits of tokenization. For instance, in real estate, tokenization allows for fractional ownership, lowering entry barriers for investors and increasing the liquidity of a traditionally illiquid market. In the art world, tokenization not only simplifies transactions but also enhances provenance tracking, thus combating fraud and ensuring the authenticity of artworks.

Today, tokenization stands on the cusp of mainstream adoption, with industries exploring its potential to revolutionize asset management, increase market efficiencies, and enhance accessibility. The journey from ancient tokens to modern blockchain platforms reflects a significant transformation in how societies understand and manage ownership and value. As regulations evolve and technology advances, tokenization is likely to play a pivotal role in shaping the future of global economies, offering a more inclusive, transparent, and efficient system for managing a wide array of assets.

2. Technological Foundations

Generally, the process of tokenization involves five design features that allow to link between the crypto markets and the markets for the reference assets. These design choices can help distinguish token types and help determine each type’s impact on traditional financial markets.:

1. A blockchain,
2. A reference asset,
3. A mechanism to assess the value of the reference asset,
4. A means to store and/or provide custody for the reference asset,

5. A mechanism to facilitate redemptions of the token and/or the reference asset.

2.1 Types of Blockchain

The first and most impacting element is the underlying blockchain on which the crypto tokens are issued, stored, and transacted. Blockchains are divided into two macro-categories: Permissioned and Permissionless.

2.1.1 Permissioned Blockchain

The permissioned blockchains are blockchains that are closed or have an access control layer. This additional layer of security dictate how each participant can contribute to the network and what they can access. The user would need permission from the network owner to become part of the latter. Technically, a user can only access, read and write information on the blockchain if they are given access to it.

Furthermore, a permissioned blockchain also supports customization. Hence, identity verification can also be done to let people into the permissioned network, instead of having the network owner approve each user. Users would ideally still be able to perform only certain activities, based on the blockchain's designated permissions.

Sometimes referred to as "private blockchains" these blockchains are considered to be partially decentralized. The cause is that the network is distributed across known participants.

Some of the defining characteristics of a permissioned blockchain are deeply connected to security. Since there is an access control layer, private blockchains are seen as more secure alternatives to public blockchain systems like Bitcoin.

Permissioned blockchains are also not anonymous and are usually developed by private entities like businesses and private organizations.

Because of the considerations reported above, the main characteristics of a private blockchain are the following (see Figure 1):

- *Decisions are authorized by a private group*: Contrary to permissionless networks, permissioned networks are not consensus-based. Instead, decisions are made by the owners of the network through a central, pre-defined level.
- *Decentralization isn't fixed:* Unlike Bitcoin, which is a fully decentralized blockchain, private blockchains can be fully centralized or partially decentralized. The members typically decide on the network's level of decentralization.
- *Transparency is not required:* Permissioned blockchains do not need to be transparent. Transparency is optional, as most permissioned blockchain networks are specifically intended to not be transparent for security purposes. Levels of transparency usually depend on the goals of the organization running the blockchain network.

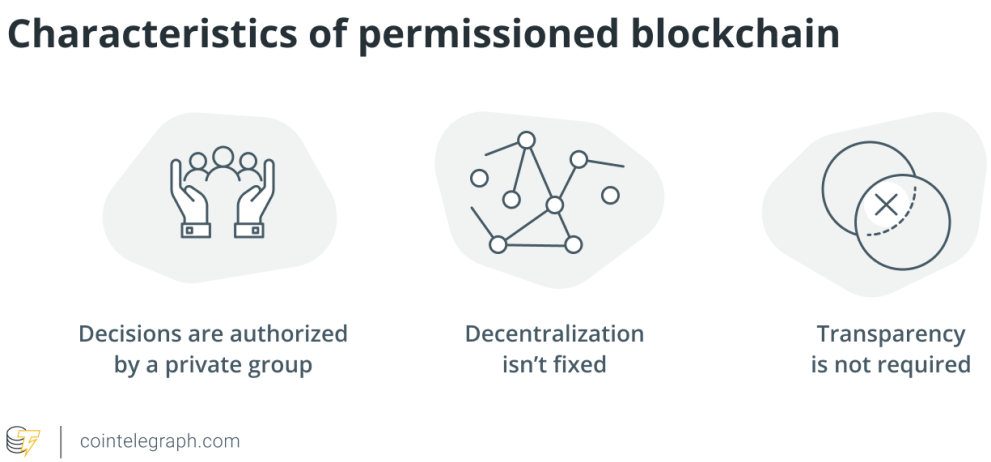

Figure 1: Characteristics of permissioned blockchain (cointelegraph.com, 2024).

2.1.2 Advantages and Disadvantages of Permissioned Blockchain

Following the characteristics mentioned above, a private blockchain could grant the user some benefit, but there are also a few downsides.

Regarding the advantages in choosing a private blockchain, the four noteworthy are:

- *High level of privacy and security*: Without having been verified or granted permission, an outsider cannot access or alter transaction information.

- *Flexibility*: It can be partially or fully centralized, giving the user more freedom to participate without having to worry about the risks associated with a highly centralized network.
- *Highly customizable*: It could assume various configurations and can be designed to meet the specific organization's needs.
- *Scalable*: It is also scalable and high-performing due to the limited number of nodes needed to manage transaction verifications.

Despite the advantages outlined above, there are still some risks and disadvantages associated with this type of blockchain among which there are:

- *Lack of transparency and risk of corruption*: Precisely because it's limited to only some people and is controlled by a private group, there is a high risk of collusion. Nonetheless, while deemed secure, a permissioned blockchain's security is also dependent on its members' integrity.

  In fact, a person or group with control over the network could decide to alter data for their own benefit. In this regard, the network's lack of transparency becomes a major downside.
- *Censorship*: Especially for businesses that need to operate under certain rules and regulations.

2.2 Permissionless Blockchains

On the opposite side stand the permissionless blockchain, that allows anyone to take part in the network and freely access information as it is decentralized and open to the public. It's called "permissionless" because there are no gatekeepers and no censorship that means that anyone who wants to access the blockchain does not need to provide identification documents.

Unlike the private blockchain, transaction information stored on the permissionless blockchains is validated by the public as there is no regulatory body or authority and the network relies on the public to reach a consensus concerning the validity of transactions.

Since it is accessible to the public, the typical trade-off of permissionless blockchains is speed. They tend to be slower than permissioned counterparts, which only have a few

members, and they are characterized by the transparency of their transactions and the anonymity of their users. They also favour open-source development.

That said, what characterize this type of blockchains are the following properties (see Figure 2):

- *Decentralization*: Typically decentralized, they don't allow a single entity alone to edit the ledger, shut down the network or alter its protocols. This is secured by the consensus protocol, which relies on the majority and their sense of integrity as it requires the agreement of more than 50% of its users.
- *Transparency:* Users within a permissionless network can access all types of information.
- *Anonymity:* Permissionless blockchains do not ask users for their identification or personal information (e.g. KYC = "Know Your Customer") when they create an address.
- *Tokens:* They allow the utilization of tokens or digital assets. These typically serve as incentives for users to take part in the network. Tokens and assets can either increase or decrease in value over time, depending on the market.

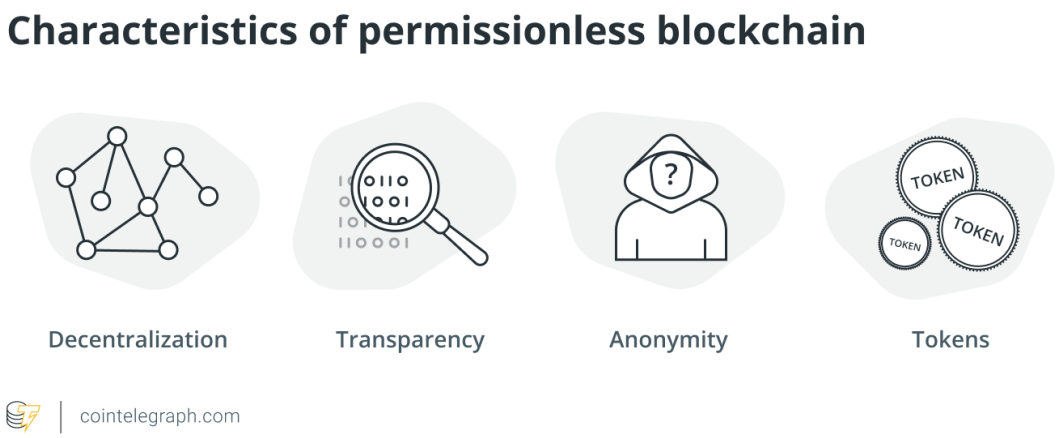

Figure 2: Characteristics of permissionless blockchain (cointelegraph.com, 2024).

2.2.2 Advantages and Disadvantages of Permissionless Blockchain

As said, permissionless blockchains differs from the private one from their core infrastructure and this, certainly, led to a set of different advantages and disadvantages.

Below is presented a list of the most notable advantages:

- *High level of transparency:* Because it is highly decentralized and spans across a large network, transparency facilitates fast reconciliation between unknown parties.
- *Decentralization*: In fact, information is not stored in any central repository, thereby making the public record secure, reliable and accessible to all. For this reason, it is also considered virtually unhackable.
- *Security and resistance to censorship:* Because it is highly accessible by users globally and hackers will face hard challenges trying to infiltrate the network as there is no single repository to target, and they, for example would have to attack 51% of the network to override its consensus mechanisms.

However, the disadvantages associated with a permissionless blockchain are various and below are reported the most impacting ones:

- *Energy Requirements:* One of the biggest challenges faced by this type of blockchain is the power needed to run the network as it requires large amounts of energy and computing power to achieve consensus.
- *Slow and hardly scalable:* As it's typically a large network, it is usually slower than private blockchain and harder to scale. For these reasons, it's difficult for some companies to adopt permissionless networks as an enterprise solution for their organization.
- *Less privacy:* Due to its public nature, there is also less privacy over transaction information, even if it grants any user a strong anonymity.
- *Anonymity:* it could also be considered a downside of permissionless systems as anyone can participate in the network and is impossible to readily filter out malicious players or fraudsters.

Considering what was reported in this paragraph, below is a summary of the main differences between a private and a permissionless blockchain (Table 1) and an example of tokens issued on permissioned and permissionless blockchains (Table 2).

Key differences between a permissioned and a permissionless blockchain

Permissioned	Permissionless
Closed; Requires permission to join the network and participate in consensus	**Public**; Does not require permission to join the network and participate in consensus
Incrementally decentralized to fully centralized; A governing authority acts as a gatekeeper	Fully decentralized, no gatekeepers
Transactions are private	Transactions are transparent and accessible
Speed and high performance	Slow transaction speed
Scalable network	Difficult to scale
Energy-efficient	Consumes a lot of energy
Development by private entities; Less mindshare	Development is open-source; More mindshare, as there are more developers
Governing authority provides a certain level of trust in the system	Trustless; The maths provide the proof
Consensus is reached quickly because computations are less complex due to limited users	Consensus takes longer to reach due to network size and complexity of computations

cointelegraph.com

Table 1: Key differences between permissioned and permissionless blockchains (cointelegraph.com, 2024).

Token Issuer	Token Name	Token Blockchain	Blockchain Type	First Issued
European Investment Bank	Bond-specific tokens	GS DAP	Permissioned	Nov-22
European Investment Bank	Bond-specific tokens	HSBC Orion	Permissioned	Jan-23
Onyx by J.P. Morgan	Repo security-specific tokens	Onyx Digital Assets	Permissioned	Nov-20
Obligate	Bond-specific tokens	Polygon	Permissionless	Mar-23
Franklin Templeton	BENJI	Stellar & Polygon	Permissionless	Apr-23
Ondo Finance	OUSG	Ethereum	Permissionless	Jan-23
RealT Tokens	Multiple, property specific tokens	Ethereum	Permissionless	Nov-21
MatrixDock	STBT	Ethereum	Permissionless	Feb-23
Lofty	Multiple, property specific tokens	Algorand	Permissionless	Aug-22
Tangible	USDR	Polygon	Permissionless	Oct-22
Aktionariat	DAKS	Ethereum	Permissionless	Jan-21
Agrotoken	SOYA	Ethereum	Permissionless	Mar-21
Agrotoken	CORA	Ethereum	Permissionless	Sep-21
Agrotoken	WHEA	Ethereum	Permissionless	Dec-21
Paxos Trust Company	PAXG	Ethereum	Permissionless	Sep-19
TG Commodities Limited	TXAUT	Ethereum	Permissionless	Jan-20
Vave	Property-specific token, bundled token	Ethereum	Permissionless	Aug-23
Toucan Protocol	TCO2	Polygon& Celo	Permissionless	Oct-21
Centrifuge	DROP/TIN	Ethereum	Permissionless	Jun-21
Goldfinch	Pool-specific tokens	Ethereum	Permissionless	Nov-21

Table 2: Tokenization Examples with Blockchain Characteristics (Carapella et al., 2023).

3. Tokenization Market Analysis

This chapter explores the rapidly evolving world of tokenized assets, a key innovation within the blockchain ecosystem that is transforming how traditional assets are managed and traded on public blockchains. It'll be focused on the diverse range of assets that have been tokenized, spacing from Real Estate to the Financial securities market. Through a detailed examination of current trends, technologies, and market data, this chapter will provide insights into how tokenization is reshaping the landscape of global finance and paving the way for the future of asset management.

Recent studies forecast substantial growth in the asset tokenization market. For instance, a report by the World Economic Forum (2021) *Digital Assets, Distributed Ledger Technology, and the Future of Capital Markets* suggests that the adoption of blockchain for asset tokenization could democratize access to investment opportunities, potentially increasing market efficiency and reducing transaction costs globally. The report highlights that as blockchain technology matures and regulatory frameworks evolve, the widespread adoption of tokenized assets could fundamentally reshape financial markets.

According to a study by Boston Consulting Group (2022) *Relevance of on-chain asset tokenization in 'crypto winter',* tokenization could represent a significant breakthrough in asset management, with the potential market value reaching up to $16 trillion. This growth

is driven by increasing trust in blockchain technologies, the evolution of regulatory frameworks, and adoption by global financial institutions.

Furthermore, a report by Roland Berger (2023) *Tokenization of Real-World Assets*, the market value of tokenized assets could exceed $10 trillion by 2030, highlighting the transformative impact this technology could have across sectors such as real estate, art, commodities, and financial securities.

As asset tokenization is deeply related to cryptocurrency, which adoption continues to grow with around 562 million people worldwide now using digital currencies, approximately 7% of the global population, it is remarkable to compare this level of adoption with the one in the early days of the internet in 2000, when 361 million people, or 6% of the world's population, were online.

As stated in the report by 21.co (2023) *"The State of Tokenization",* the S-curve of the cryptocurrency vs internet adoption, in Figure 3 below, gives a precise overview of the stage in which the market currently is, and the potential for the future years.

In fact, between 2016 and 2022, the growth of cryptocurrency ownership has significantly outpaced the early expansion of internet usage. Specifically, the compound annual growth rate [7] (CAGR) for the number of crypto owners was approximately 89%, far exceeding the 65% CAGR seen in internet adoption from 1994 to 2000. This remarkable acceleration highlights the rapid embrace of digital currencies.

Looking to the future, the forecast for crypto ownership over the next 22 years is based on an expected CAGR of 12.45%. This growth rate mirrors the expansion of internet users from 2000 to 2022, suggesting that cryptocurrency adoption could follow a similar trajectory of widespread global integration.

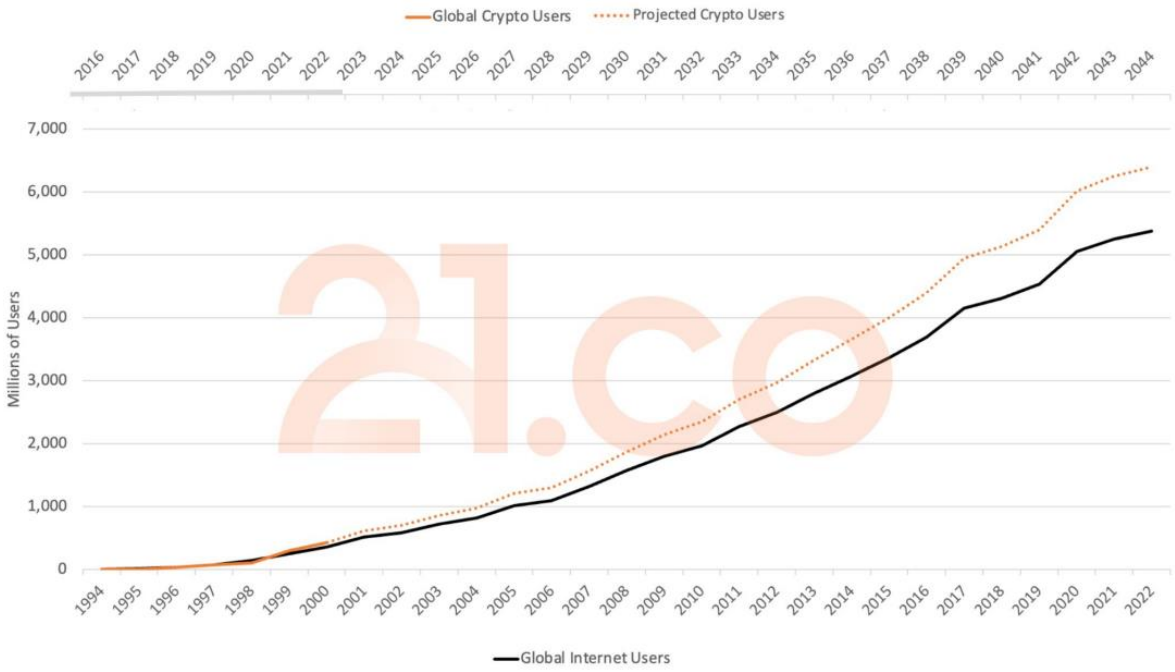

Figure 3: S-curve, cryptocurrency vs internet adoption (21.co, 2023).

3.1 Digital Assets Owner's Demographic

To gain a deeper understanding of this data's implications, it is crucial to delve into the demographics of those who own digital assets (see Figure 4). A key observation is that countries with high levels of cryptocurrency ownership generally possess strong internet connectivity and well-established banking systems. These factors play a significant role in facilitating easier and more widespread access to digital assets, as they provide the necessary infrastructure for fast transactions and secure storage.

The growth in crypto ownership over the past year, from 2023 to 2024, further highlights these regional disparities. According to a report by Triple-A (2024) *The State of Global Cryptocurrency Ownership in 2024,* in Asia, there has been a notable growth rate of about 22%, reflecting a steady increase in adoption, driven by improving digital infrastructures and growing interest in cryptocurrencies. North America has seen a more pronounced rise, with a 38% increase in ownership, likely fuelled by the region's advanced technological landscape and the growing integration of digital assets into mainstream financial systems.

Europe stands out with the most significant growth, recording a 60% surge in crypto ownership over the same period. This remarkable increase suggests that European countries,

with their highly developed internet and banking infrastructures, are at the forefront of embracing digital assets, thanks to the efforts to have a strong regulatory framework.

It is worth mentioning South America, which has experienced a growth of over 100%. This remarkable increase can be attributed, in large part, to the challenging economic conditions faced by many countries in the region. A significant factor that has played a crucial role in driving this growth is the severe devaluation of national currencies, often reaching levels of hyperinflation. These economic hardships have pushed individuals and businesses alike to seek refuge in cryptocurrencies as an alternative means of preserving value (e.g. USD stablecoin, gold...) and conducting transactions, thereby fuelling the rapid adoption of digital assets across the continent. This trend underscores how, in a context of economic instability, cryptocurrencies can play a crucial role in preventing financial deterioration, as people seek out more stable and reliable financial solutions amidst ongoing fiscal challenges.

Figure 4: State of global cryptocurrency ownership by continent (Triple-A, 2024).

Furthermore, as shown in Figure 5, most of the people that make up the market, around 70%, are aged between 25 and 44, fairly balanced in terms of gender. This highlights a significant potential for adoption growth, as it underscores the natural affinity of younger generations for emerging technologies.

These generations, in the coming years, are poised to become the primary drivers of development and innovation within this sector. Their willingness to embrace new technologies, combined with their increasing economic and social influence, suggests that

they will play a crucial role in steering the expansion and evolution of this field, solidifying its importance and strategic impact on a global scale.

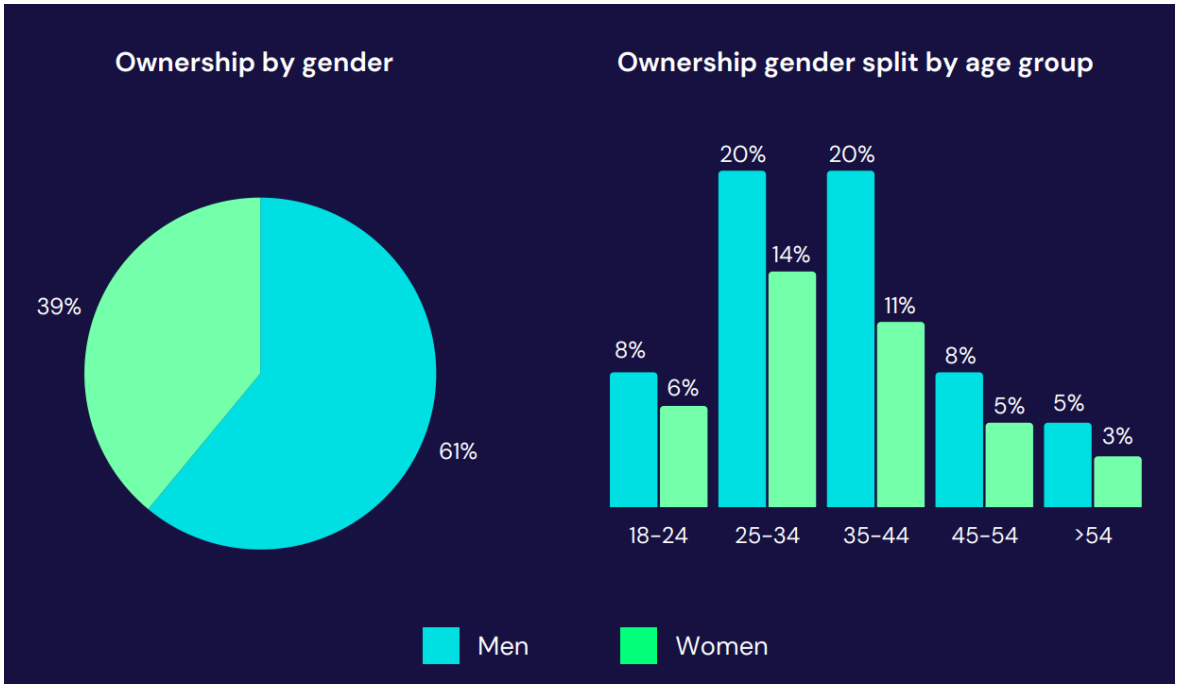

Figure 5: Deep dive into cryptocurrency owners' gender and age (Triple-A, 2024).

3.2 Evaluation of Sectors Impacted by Asset Tokenization

By now, more than 10% of these crypto users have embraced tokenized assets, especially USD stablecoins [8] often referred to as digital dollars accounting for approximately 10% of the entire cryptocurrency market (see figure 6) signalling a significant shift towards the integration of traditional finance with blockchain technology.

This positions them as a significant force, second only to the major cryptocurrencies Bitcoin and Ethereum. The fact that stablecoins have garnered such a substantial share of the market underscores their importance and reliability as a digital financial instrument. This evolution points to a future where stablecoins continue to play a pivotal role in the broader adoption and utilization of blockchain technology, driving further innovation and stability within the cryptocurrency space.

Figure 6: Stablecoins Total Market Capitalization (DefiLlama, 2024).

As of July 2024, the landscape of tokenized assets has expanded to include approximately 62 million holders worldwide. It is essential to emphasize that an overwhelming 99% of these tokenized assets are stablecoins, which highlights their dominant role within the market. This dominance indicates that stablecoins have successfully achieved widespread adoption and integration into the financial ecosystem, becoming a cornerstone of the digital asset landscape. In contrast, other forms of tokenized assets, such as commodities or real-estate sector, remain in a development stage, largely experimental and not yet widely scaled or adopted (Figure 7).

Beyond stablecoins, which will not be explored in detail in this paper, the leading application of tokenization is found in the domain of tokenized commodities, which has attracted a cumulative user base of approximately 125,000 individuals. This indicates a substantial and growing interest in digitizing tangible assets such as gold and other precious materials (e.g. Paxos), making them more accessible and tradable on blockchain platforms. Following this, government securities, including digital versions of government bonds and other debt instruments, have garnered around 9,000 active users (e.g. Securitize). This reflects a burgeoning recognition of the benefits of bringing traditionally stable and secure financial instruments into the digital realm.

Real estate tokenization comes next, with approximately 7,000 users. This involves the digital representation of property ownership, allowing for fractional ownership and increased liquidity in the real estate market, which has traditionally been illiquid and difficult to trade (e.g. RealT). Lastly, asset-based finance, which includes the tokenization of

collateralized assets used to secure loans and other financial products, has attracted around 6,000 users. These numbers illustrate that while these sectors are beginning to gain traction, they remain in the early stages of adoption compared to the more established market for stablecoins.

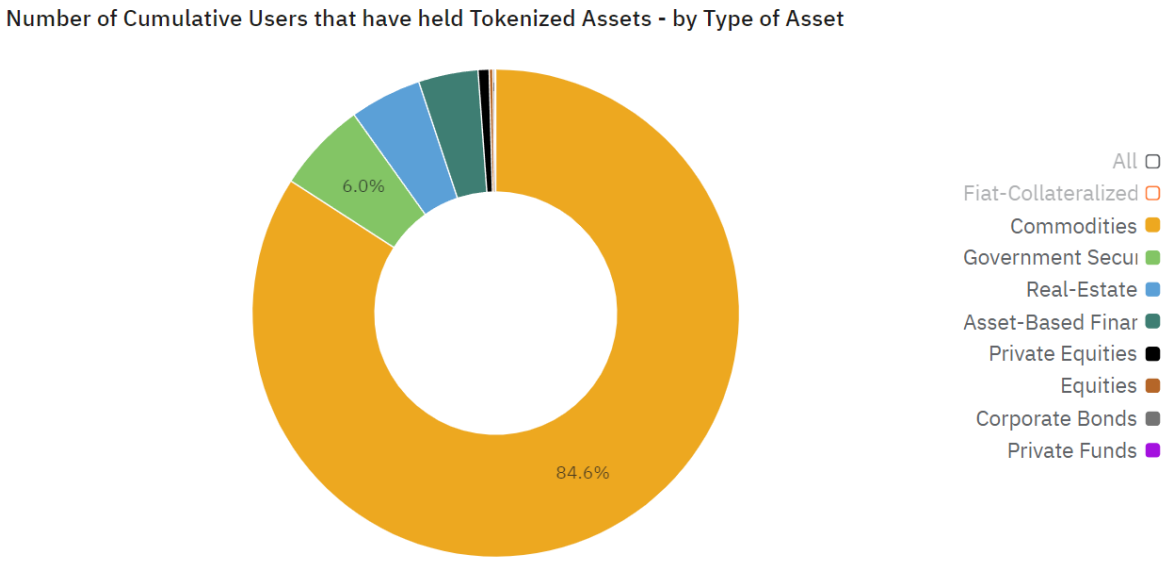

Figure 7: Number of cumulative users that have held tokenized assets, by type of asset, stablecoins excluded (dune.com, 2024).

Currently tokenized assets across public blockchains have reached a total value of $85 billion. As illustrated in the Figure 8 below, which showcases the largest projects by market capitalization, it becomes evident that Ethereum's blockchain holds a dominant position in the tokenization space as Ethereum alone commands more than 90% of the market, with its total value exceeding $80 billion.

This dominance is supported by Ethereum's highly active and robust ecosystem, boasting over 6.5 million users [9] and nearly 9,000 developers actively contributing on a monthly basis [10]. These clearly reflect Ethereum's pivotal role in driving innovation and infrastructure within the tokenization landscape.

This paper will not delve into stablecoin projects such as USDT by Tether and USDC by Circle, despite their essential role in facilitating asset trading within the broader cryptocurrency market. Stablecoins are critical for enabling liquidity and smooth transactions in the tokenized asset market, however, they fall outside the scope of this analysis as it is important to note that various governments (e.g. China, Europe), have

initiated experimental projects related to Central Bank Digital Currencies (CBDCs). These CBDCs could potentially replace stablecoins in the future, as they are issued and regulated by governmental authorities, rather than private companies, ensuring a higher level of oversight and control.

A noteworthy aspect of this space is the diversity of sectors represented by the remaining projects, which range from commodities and government securities to private funds and real estate. This variety underscores the significant interest in tokenization across various industries, even though many of these sectors are still in the experimental phase. The cross-industry appeal of tokenization suggests that it holds the potential to revolutionize multiple facets of the global financial system.

Among the most prominent projects in the commodity sector, Paxos stands out. This company primarily focuses on the tokenization of gold, with a current market capitalization of approximately $1 billion. While this represents a significant decrease of around 75% from its 2023 valuation, the decline is not entirely unexpected.

Gold is traditionally seen as a safe-haven asset, and with 2024 marking a period of rapid expansion for the cryptocurrency market, many investors have shifted away from stable assets like gold in favour of more speculative, high-growth opportunities. In fact, it's well-known that in bullish periods, investors tend to liquidate their safer holdings in exchange for riskier investments, while during bear markets, they typically revert to stable assets, with gold being a prime example of this behaviour.

Following Paxos in market capitalization is Securitize, which operates in the fields of government securities and private funds. Securitize now manages over $500 million in assets, an extraordinary growth of more than 3,000% compared to the previous year. This surge in growth is a strong indicator of the increasing interest, particularly from institutional investors, in the opportunities presented by the tokenization of traditional financial instruments. Securitize's success highlights the growing appeal of digitizing assets that were once restricted to more conventional markets.

Real estate is another sector that has seen notable developments through tokenization, with RealT leading the charge. This project, with a market capitalization of around $200 million, has experienced nearly 100% growth over the past year. RealT is poised to radically transform the way investors engage with the real estate market, offering new opportunities

for fractional ownership and liquidity that were previously unavailable in such a traditionally illiquid asset class.

Project	Type	Blockchain	Market Cap	Market Share	1Y Change
Tether	Commodities, Fiat-Collateralized Stablecoins	Ethereum	$55.27b	65.18%	33.1%
Circle	Fiat-Collateralized Stablecoins	Ethereum	$25.37b	29.91%	-0.2%
Paxos	Commodities, Fiat-Collateralized Stablecoins	Ethereum	$993.63m	1.17%	-75.5%
Securitize	Government Securities, Private Funds	Avalanche, Ethereum, Polygon	$516.92m	0.61%	3371.1%
Ondo Finance	Government Securities	Arbitrum, Ethereum, Mantle	$457.76m	0.54%	190.6%
Franklin Templeton	Government Securities	Arbitrum, Polygon, Stellar	$402.49m	0.47%	41.0%
Centrifuge	Asset-Based Finance	Ethereum	$342.44m	0.40%	44.5%
TrustToken	Fiat-Collateralized Stablecoins	Ethereum	$317.33m	0.37%	-56.4%
Hashnote	Government Securities	Ethereum	$224.87m	0.27%	3681.3%
RealT Tokens	Real-Estate	Ethereum, Gnosis	$187.73m	0.22%	96.8%

Figure 8: Top 10 tokenization project by market capitalization (dune.com, 2024).

A more comprehensive analysis of the main sectors impacted by tokenization and the most promising projects in this space, will be provided in the next chapter, where the current leading use cases will be explored in detail. This will provide a clearer picture of how tokenization is already beginning to reshape various industries and the potential it holds for the future.

4. Real-World Examples of Tokenized Asset Use Cases

This chapter takes a closer look at how tokenized assets are being used in various industries, like finance, real estate, and commodities. By sharing real-world examples, it shows how this technology is opening new possibilities for investors and businesses, and how it's starting to have a real impact on the global economy.

As previously mentioned, tokenization is fundamentally changing how assets are owned and traded across industries. This innovative approach is transforming traditional markets by boosting liquidity and efficiency, while also improving transparency and security. Furthermore, it lowers entry barriers, making investment opportunities more available to a wider range of investors.

A brief overview of the trending sectors impacted by this technology is given below:

1. **Real Estate**: Tokenization allows fractional ownership of property, making real estate investment more liquid and accessible. Investors can buy tokens representing shares of a building, land, or development projects.
2. **Art and Collectibles**: It allows artists and collectors to offer fractional ownership of their pieces, making the art market accessible also to retail investors. This approach not only democratizes investment opportunities but also improves the traceability and verification of both authenticity and ownership, bringing greater transparency to this sector.
3. **Commodities**: Tokenization can be applied to commodities like gold, oil, or agricultural products, facilitating easier and more transparent transactions. It also provides a verified record of the asset's entire life cycle.
4. **Intellectual Property**: Rights to intellectual property, such as patents, trademarks, and copyrights can be converted into tokens. This process gives creators precise control over how their IP is licensed and used, offering new opportunities for monetizing these assets while being protected.
5. **Financial Securities**: Stocks, bonds, and other financial instruments can be tokenized to streamline the issuance, trading, and management processes. This can reduce costs, increase transparency, and open investment opportunities to a broader audience.

Each type of tokenized asset opens new ways for investment and asset management, reflecting a shift towards more integrated, transparent, and participatory financial ecosystems.

This section provides an in-depth analysis of the different types of assets that can be tokenized, with a focus on the most prominent emerging use cases within each sector.

4.1 Real Estate Tokenization

Real estate tokenization is a transformative approach to property investment that leverages blockchain technology. This method involves converting property ownership rights into

digital tokens, effectively creating a digital representation of an assets that can be traded on blockchain platforms (e.g. Ethereum).

One of the most significant advantages of real estate tokenization is that it allows for fractional ownership of properties. Investors can buy tokens that represent a share of the property, making real estate investment accessible to a broader range of investors by lowering entry costs and capital requirements.

Real estate is traditionally an illiquid asset class. Tokenization introduces liquidity to this market, as tokens can be easily bought and sold on various exchanges. This liquidity also allows for quicker and more efficient transactions compared to traditional real estate sales processes.

Furthermore, blockchain technology provides a secure and transparent record-keeping mechanism. Every transaction involving the tokenized property is recorded on the blockchain, providing a clear trail of ownership and financial transactions. This reduces the potential for fraud and errors, enhancing trust among investors.

By tokenizing real estate, investors from around the world can invest in markets previously inaccessible to them due to geographic or regulatory restrictions. This global access diversifies investment opportunities and can potentially stabilize returns.

The use of blockchain technology can significantly reduce transaction costs associated with real estate dealings, such as fees for legal services, brokers, and banks. Smart contracts [11] automate many of the processes, further cutting down on time and expense.

RealT stands at the forefront of real estate tokenization, allowing individuals from every country to purchase tokens representing fractional ownership in properties.

The process is straightforward: potential investors can visit the RealT website, purchase tokens, and complete the necessary documentation all in one session. This method drastically reduces the time it typically takes to buy real estate, from weeks or months to just minutes.

The figure 9 provides an illustrative example of several tokenized properties, detailing how each property has been divided into fractional ownership, the Token Supply, and specifying the corresponding cost per individual token, the Token Price. Additionally, the figure highlights the number of investors who have actively participated in each asset, broken down by the blockchain used for these transactions, Ethereum and Gnosis respectively.

Property	Type	Token Price	Token Supply	Holders on Ethereum	Holders on Gnosis
581-587 Jefferson Ave, Rochester, NY 14611	real_estate_rental	$41.50	10000.00	95	1003
9133 Devonshire Rd, Detroit, MI 48224	real_estate_rental	$58.27	1300.00	11	255
18433 Faust Ave, Detroit, MI 48219	real_estate_rental	$59.00	1300.00	12	224
14918 Joy Rd, Detroit, MI 48228	real_estate_rental	$49.44	14000.00	53	419
893-895 W Philadelphia St, Detroit, MI 48202	real_estate_rental	$54.95	1800.00	16	243
15379 Patton St, Detroit, MI 48223	real_estate_rental	$51.80	1000.00	4	261
882-884 Pingree St, Detroit, MI 48202	real_estate_rental	$53.76	1700.00	3	281
4000 Taylor St, Detroit, MI 48204	real_estate_rental	$54.34	1100.00	3	184
3747 Scovel Pl, Detroit, MI 48208	real_estate_rental	$50.19	13800.00	4	730

Figure 9: Examples of tokenized properties by RealT (dune.com, 2024).

Once you own tokens, you begin to receive income from the property, calculated as a percentage of the net rent relative to your total investment (see Figure 10). Payments are made weekly, which enhances the liquidity and ease of income flow for investors. The tokens not only represent equity in the property but also allow for easy trading, adding a layer of liquidity to an asset class traditionally considered illiquid.

RealT properties are managed by professional property management companies, so investors are not directly involved in the maintenance or management of the properties. This provides a passive income stream without having to constantly monitor the investment.

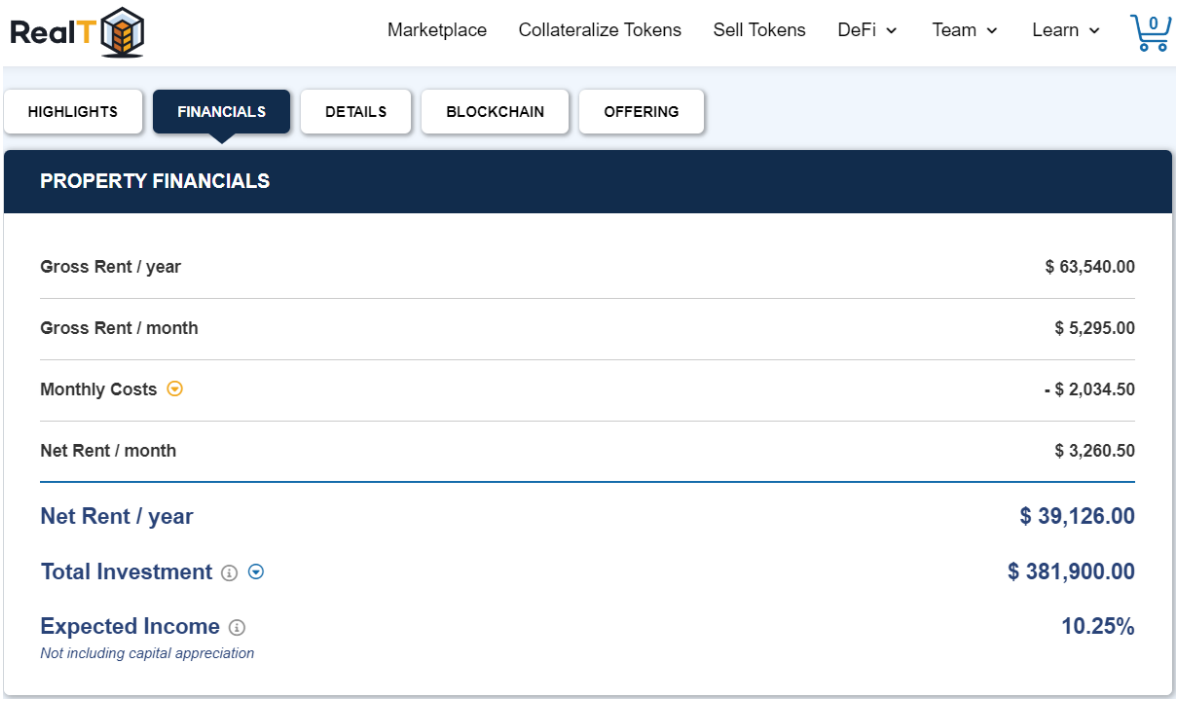

Figure 10: Example of a property financial and expected income (RealT, 2024).

As of today, the company has successfully tokenized over 600 properties, generating more than $10 million in cumulative returns for its investors [12]. This substantial figure serves as a clear indicator of the increasing interest and confidence in the real estate tokenization market, reflecting its potential to transform traditional property investment.

However, despite this notable achievement, the journey toward making real estate tokenization a mainstream practice remains lengthy. To truly grasp the magnitude of the opportunity, it's important to consider that the global real estate market has an estimated market capitalization exceeding $500 trillion. This immense figure underscores not only the vast scope of the industry but also the significant growth and innovation required to fully integrate tokenization within this space.

While real estate tokenization offers numerous benefits, it also comes with challenges that need to be addressed, as for instance the legal framework that is still in developing since jurisdictions may have different regulations governing blockchain technology and securities, thus impacting how tokens can be issued and traded.

Furthermore, another crucial challenge is that the market is still at his early stage, as the concept of real estate tokenization is still new and may require time for widespread adoption.

Traditional investors and real estate professionals may need education on the benefits and risks associated with such technologies.

In conclusion, real estate tokenization represents a significant shift in how property investment is conducted, offering an innovative way to enhance liquidity, transparency, and accessibility in the real estate market. As the technology and regulatory frameworks evolve, it has the potential to become a mainstream method for real estate transactions and investments.

4.2 Art and Collectibles Tokenization

The art market benefits from tokenization by solving some of its longest-standing issues: liquidity and accessibility. In fact, tokenizing art pieces allows artists and collectors to sell fractional shares of their works, making art investments more accessible to the public and not just wealthy people or institutions.

Furthermore, blockchain provides a tamper-proof record of ownership and provenance and this is particularly valuable in the art market, where authenticity and history significantly impact an item's value.

One of the most interesting projects concerning this market segment is Masterworks.io, that is a pioneering platform in the art tokenization sector. Their business model revolved around using blockchain technology to create a decentralized art gallery where shares of fine art are bought and sold (see Figure 11). Below their business model is presented:

Masterworks.io begins by identifying and purchasing artworks by well-known artists. These pieces are generally selected based on historical performance data and their potential for appreciation. The platform utilizes its proprietary data and research to make informed buying decisions. Once an artwork is acquired, Masterworks.io files an offering circular with the U.S. Securities and Exchange Commission (SEC). This document details the investment offering, allowing the artwork to be tokenized. After SEC qualification, shares representing an investment in the artwork are created. Each share corresponds to a fractional interest in the painting.

These shares are then offered to investors on the Masterworks.io platform. Investors can purchase shares in specific artworks, effectively gaining fractional ownership. This opens

the opportunity for retail investors to participate in the high-value art market, which was traditionally accessible only to the wealthy or institutional investors.

Once the shares are sold, Masterworks.io manages the artwork, including insurance, storage, and eventual sale. The company aims to hold each piece for approximately three to ten years, depending on the art market conditions and the specific investment strategy for each piece.

To be able to offer this service, Masterworks.io charges an initial offering fee for each artwork, typically around 1-10% of the offering size. This fee covers the costs associated with sourcing, acquiring, and filing the offering of the artwork. Furthermore, the platform charges an annual management fee, generally about 1.5% of the artwork's value, to cover the ongoing expenses of insurance, storage, and transportation of the artwork.

When an artwork is sold, Masterworks.io takes a share of any profits realized beyond the original purchase price. This performance fee incentivizes the platform to maximize the sale price of the artwork. Typically, this fee is around 20% of the profits, aligning the company’s interests with those of the investors.

One of the innovations brought by this platform is the developing of their own secondary market where investors can buy and sell shares to other registered users, providing some liquidity to an otherwise illiquid investment. However, liquidity is not as high as in traditional equity markets and selling shares can be challenging if there is insufficient buyer interest.

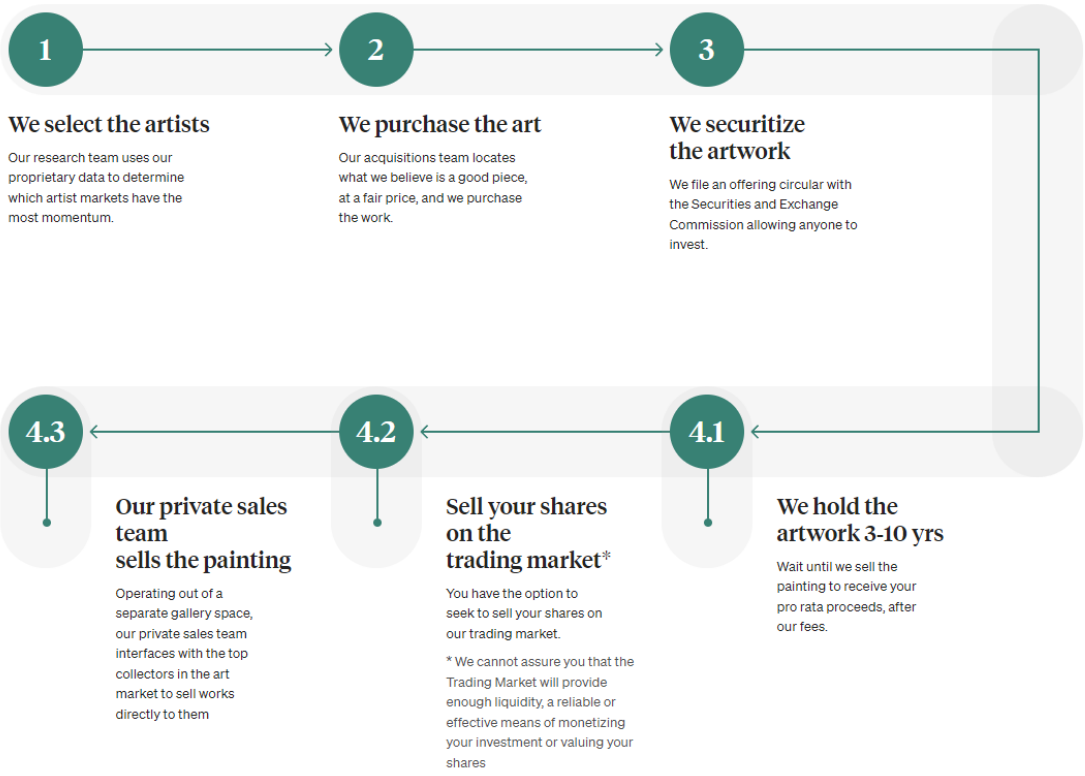

Figure 11: Masterworks.io business model (Masterworks, 2024).

This innovative approach has opened new possibilities for art investment, providing access to a market that offers potential for significant returns while also diversifying investment portfolios.

The requirement for the company to comply with SEC regulations to operate has the potential to significantly benefit smaller investors by providing them with a heightened sense of security and trust in the process. Regulatory compliance ensures that the company adheres to strict legal and financial standards, offering a layer of protection that could make this emerging market more appealing to those who may have previously been hesitant to participate.

4.3 Commodity Tokenization

Tokenizing commodities like gold, oil, and agricultural products can standardize and simplify transactions while providing more transparent and efficient marketplaces. Commodity tokens represent ownership of a physical commodity and can be traded on

digital platforms, potentially reducing the volatility and speculation often associated with these markets.

By using blockchain, each transaction along the supply chain, from production through to sale, can be recorded, offering real-time data that can enhance trust and verification in these markets. Additionally, smaller investors gain the opportunity to invest in commodities by purchasing fractional tokens, a practice that was previously more challenging due to high entry costs and complex trading systems.

The key example of commodity tokenization is Pax Gold (PAXG), a digital token that aims to simplify the buying, holding, and trading of gold through modern technology (see Figure 12).

Each PAXG token represents one ounce of physical gold of a 400 oz London Good Delivery gold bar. The physical gold is held in custody by Paxos Trust Company, ensuring that each token is fully backed by a tangible asset stored in vaults approved by the London Bullion Market Association (LBMA). The physical gold is insured, adding another layer of security for token holders. For seek of transparency, this is constantly monitored and reported in accordance with attestation standards established by the American Institute of Certified Public Accountants (AICPA) [13].

Furthermore, Paxos, is a regulated financial institution under the New York State Department of Financial Services (NYDFS). This regulatory oversight adds an additional layer of trust and security for investors.

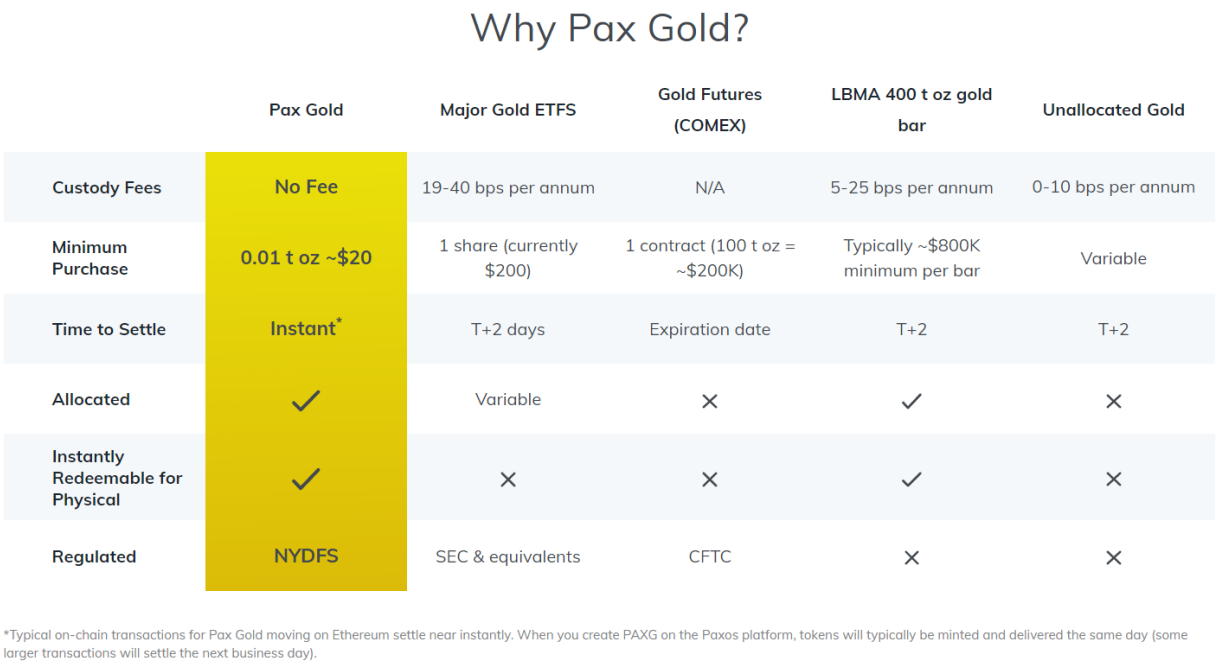

Figure 12: Pax Gold compared to other gold products (Paxos, 2024).

In traditional financial markets, investors are certainly able to purchase physical or allocated gold in any quantity they desire, but doing so comes with significant challenges and risks associated with the physical nature of the asset. Large gold bars, for instance, are not only heavy but also require secure and often expensive storage solutions to ensure their safety. This adds an ongoing cost to ownership.

Furthermore, physical gold is not easily divisible, and this lack of flexibility can make it difficult to use gold in smaller transactions or to liquidate portions of the investment as needed. The logistics of transporting large quantities of gold also complicate matters, as moving physical gold can be costly and time-consuming. As a result, selling or trading physical gold in traditional markets can be a slow, inefficient process, limiting its liquidity and accessibility.

To avoid these challenges, many investors turn to financial instruments like unallocated gold futures, Contracts for Difference (CFDs), or Exchange-Traded Funds (ETFs). These alternatives offer the convenience of trading gold without the need to manage physical assets. However, these products are merely derivatives; they do not represent actual ownership of gold. Instead, they are speculative tools that allow investors to profit from the fluctuations in gold prices without any tangible gold backing their holdings.

While these instruments make it easier to engage in gold trading and provide greater liquidity, they come with a significant drawback: they do not offer the security of a true store of value. Unlike physical gold, which has intrinsic worth as a tangible asset, these derivatives are purely financial constructs based on the assumption of price changes. Consequently, while they simplify the process of trading, they fail to deliver the value preservation that gold ownership traditionally represents, making them more suitable for short-term speculation rather than long-term investment stability.

This is where PAXG plays a crucial role, as it represents an innovative blending of traditional gold investment with modern blockchain technology, offering a secure, transparent, and flexible way to invest in gold, not only for speculative reasons. This makes PAXG an attractive option for both seasoned gold investors and newcomers to the world of digital assets.

4.4 Intellectual Property Tokenization

Intellectual property (IP) such as patents, copyrights, trademarks, and even digital assets like software and multimedia content, can be tokenized to manage and monetize these assets more effectively. Tokenization allows creators and IP owners to retain control over their works while enabling them to license or sell these rights in a more targeted and efficient manner.

An interesting project related to this field is the one of IPwe that aim to disrupt the traditional intellectual property (IP) management and monetization processes, particularly focusing on patents. Below is summarized the process used by this platform:

First, IPwe tokenizes patents by converting them into digital tokens on the blockchain. This tokenization represents a shift from physical or paper-based patent documentation to a digital form that can be easily traded, managed, and monitored as well as providing a comprehensive platform for patent analysis, management, and transaction services.

This platform utilizes artificial intelligence to analyse and value patents, offering insights that help patent owners make informed decisions about licensing, selling, or enforcing their IP portfolio. This is made possible using IPwe's Smart Intangible Asset Management (SIAM) that provides the data needed for companies to optimize their intellectual property

strategy (see Figure 13) and enabling to benchmark customers' IP portfolio also against competitors to help them in decision making process (see Figure 14).

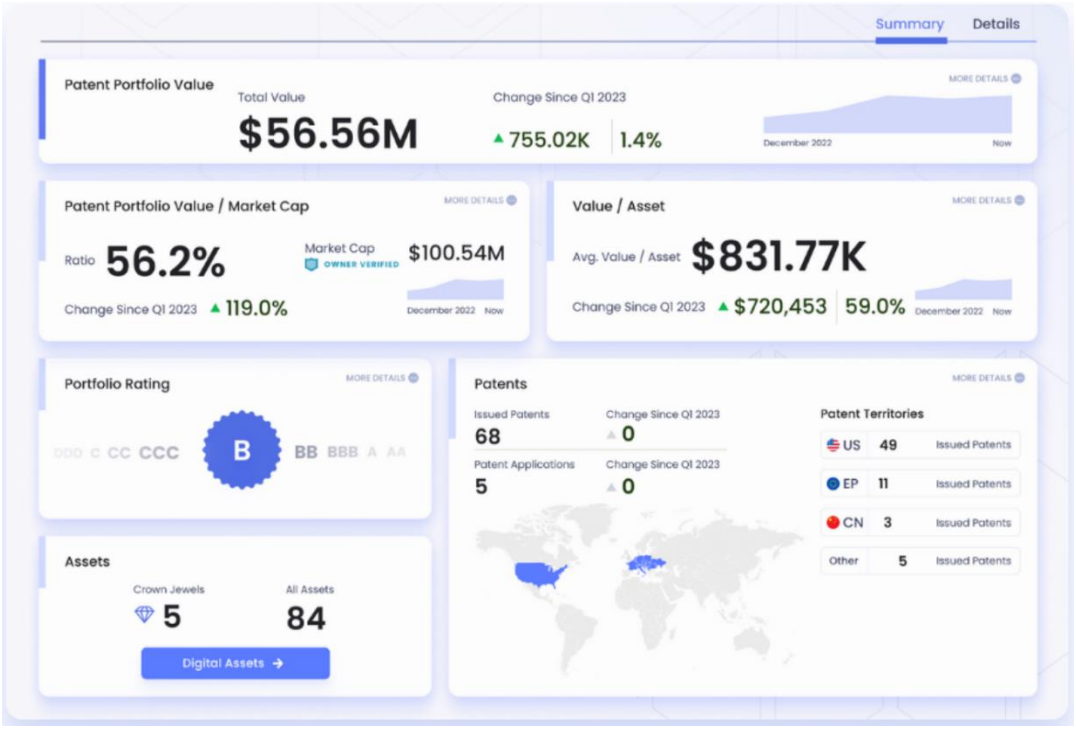

Figure 13: Overview of the Smart Intangible Asset Management dashboard (IPwe, 2024).

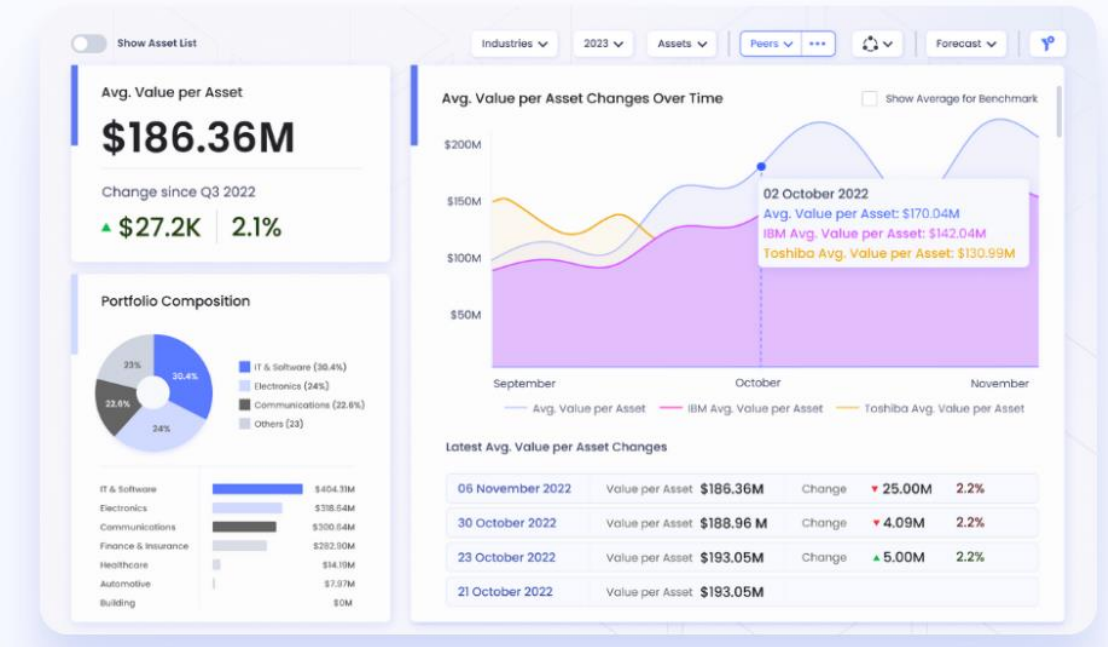

Figure 14: Dashboard comparing the IP portfolio owned against peers and competitors (IPwe, 2024).

IPwe aims to create a global marketplace for IP, where patents can be bought, sold, or licensed across borders with ease, offering solutions that address many of the inefficiencies and barriers in traditional IP management and monetization processes. As blockchain technology continues to evolve, IPwe's could play a major role in shaping the future of intellectual property management.

4.5 Financial Securities Tokenization

Tokenization also extends to financial securities, including stocks, bonds, and derivatives. By tokenizing these assets, the process of buying, selling, and trading can be streamlined, reducing the need for intermediaries such as brokers and clearinghouses. This results in faster transaction times and lower costs, with enhanced security and auditability provided by blockchain technology.

Moreover, tokenization enables the creation of customized financial products. Investors can, for instance, purchase tokens representing various types of debt and equity products, allowing for greater flexibility and personalization in portfolio management. Companies could also issue tokenized bonds directly to investors without needing to go through traditional financial institutions.

One of the most interesting solutions concerning this market is the one proposed by Securitize, a leading digital asset securities firm, which specializes in the tokenization of financial assets. The company provides a comprehensive, end-to-end platform that enables businesses to raise capital, manage shareholders, and offer liquidity through the issuance of tokenized securities. Their platform is designed to be fully compliant with U.S. regulations, making it one of the few firms capable of offering such services within the existing legal framework.

The core of Securities' business revolves around converting traditional assets into digital tokens that represent ownership or other rights, thus enabling companies to raise capital through the tokenization of various assets, including equity, real estate, debt and funds. This process involves several steps:

1. Asset Selection and Structuring;
2. Compliance;

3. Issuance.

The first step is identifying the asset to be tokenized. This could be equity in a company, a real estate property, a debt instrument, or a fund. Securitize helps structure the asset to be suitable for tokenization, which includes defining the rights of the token holders (e.g., voting rights, dividend entitlements…).

Once identified, Securitize ensures that all tokenized securities comply with relevant regulations. This includes Know Your Customer (KYC) and Anti-Money Laundering (AML) checks, as well as adherence to securities laws and get the approval from the Security Exchange Commission (SEC). Compliance is automated through smart contracts, which enforce the rules embedded in the tokens.

Then, when the asset is structured and compliance measures are in place, Securitize issues the digital tokens (Figure 15) on a blockchain like Ethereum, Algorand and others in which these tokens represent fractional ownership or claims on the underlying asset. The tokens are then distributed to investors, who can hold or trade them on secondary markets.

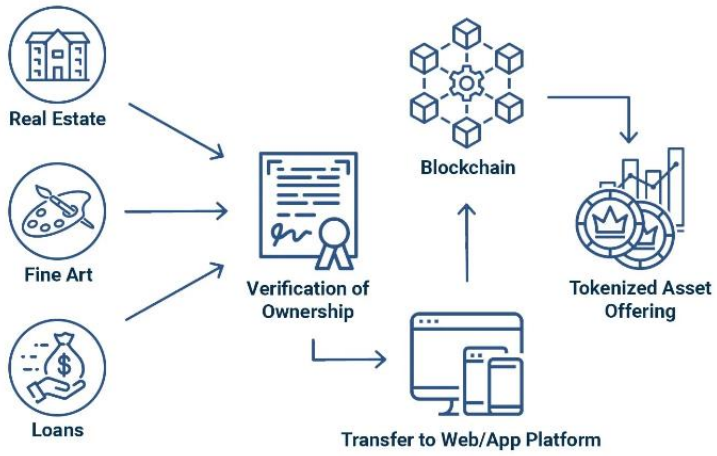

Figure 15: Tokenization process (Securitize, 2024).

Securities' platform allows various tools for managing these digital securities post-issuance.

In fact, it automates the execution of corporate actions like dividend payments, interest distributions, voting, and share buybacks. These actions are managed through smart contracts, reducing the need for manual processing.

The platform also maintains an up-to-date cap table (a record of ownership) that reflects the real-time ownership of the tokenized securities. This ensures transparency and accuracy in the management of the security holders' records and allows companies to communicate with token holders, distribute financial reports, and handle investor inquiries through their site.

Furthermore, Securitize operates its own alternative trading system (ATS) called Securitize Markets, which is regulated by the SEC and FINRA. This platform allows investors to trade tokenized securities, providing liquidity to what are typically illiquid assets (like private equity or real estate) and connects a large network of global investors, facilitating cross-border trading and expanding access to a broader investor base. This is particularly important for smaller companies or assets that might not attract institutional investors.

Securitize has partnered with various blockchain networks (e.g. Ethereum) and collaborate with major financial firms like KKR and Hamilton Lane to enhance its offerings (Figure 16).

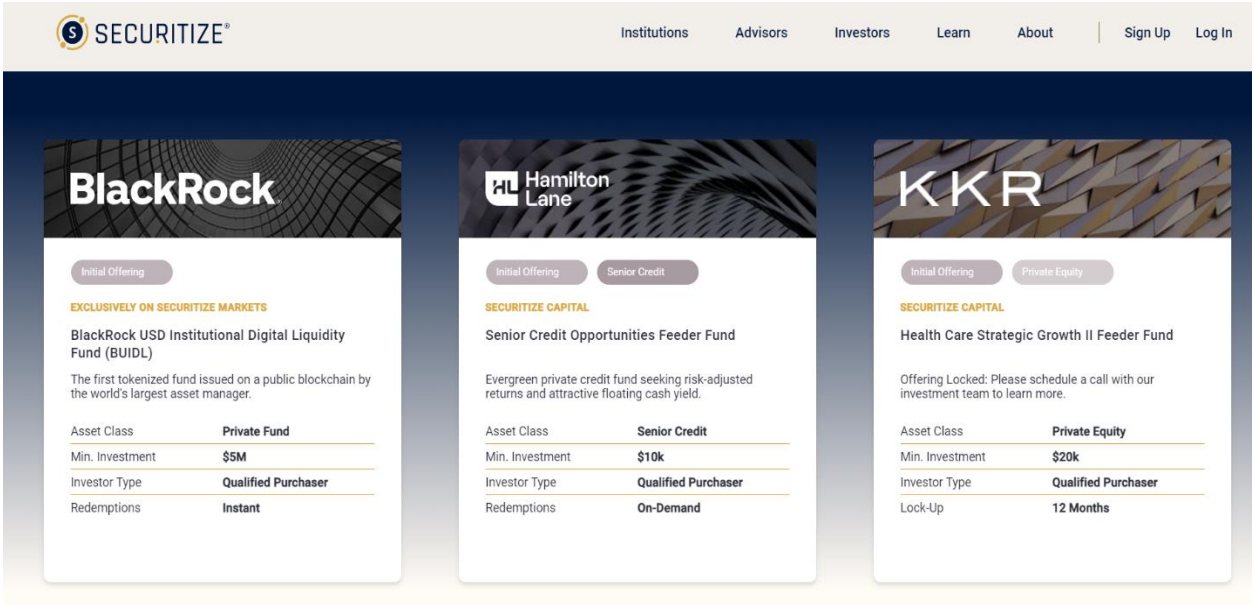

Figure 16: Examples of Securitize' tokenized assets (Securitize, 2024).

With his 1 billion $ as AUM and more then 500k accounts Securitize is at the forefront of Real-World Asset (RWA) tokenization, leveraging blockchain technology to transform how assets are issued, managed, and traded. By tokenizing assets, Securitize democratizes access

to investments that were previously limited to few investors, offering greater liquidity, transparency, and compliance.

In conclusion, the examples presented highlight how tokenized assets are revolutionizing industries by enabling more fluid, transparent, and equitable markets. As blockchain technology advances and regulations adapt to this innovation, the potential applications of tokenization are poised to expand even further. This shift could marks the beginning of a new paradigm in asset management, one that blurs the lines between traditional finance and the digital economy, creating more opportunities for investors and industries alike.

5. Tokenized Credit Default Swaps' Solution

Based on the market analysis discussed in the preceding chapters, it is evident that the financial securities sector holds significant potential for innovative opportunities, particularly with respect to the wide range of financial instruments that could be tokenized in the near future.

It has been already shown the emergence of projects centred around the tokenization and exchange of equity, debt, and fund-based products, indicating that the industry is beginning to embrace these developments.

However, the analysis also highlighted a gap: for certain financial products, such as credit default swaps (CDS), there are currently no relevant examples of successful tokenization efforts.

The inherent complexity and lack of transparency in credit default swaps transactions have long been a source of concern regarding security and accountability. In the context of CDS contracts in the blockchain, addressing information asymmetry is crucial for ensuring the efficient and transparent functioning of the market. Several potential approaches can be adopted to mitigate the problem of information asymmetry. Firstly, leveraging blockchain technology can contribute to reducing information asymmetry by facilitating transparent and immutable recordkeeping.

Additionally, smart contracts and automated verification mechanisms can reduce reliance on subjective judgement or hidden clauses. Standardized reporting requirements and timely disclosure of relevant information related to CDS contracts can also play a crucial role in addressing information asymmetry. The utilization of oracles can further enhance the

reliability of external data sources and verifiable data feeds, ensuring accurate and unbiased information is used in contract execution.

It is important to acknowledge that while these measures could effectively mitigate information asymmetry to a certain extent, complete elimination of information asymmetry may pose challenges. However, by leveraging the unique attributes of blockchain technology, in conjunction with appropriate regulatory frameworks, the problem of information asymmetry can be significantly reduced within the CDS contract market.

In this chapter, a theoretical model for the tokenization of the credit default swaps will be introduced. While the focus will remain at a conceptual level, outlining how these complex financial instruments could be adapted to a tokenized framework, a detailed practical implementation falls outside the scope of this thesis. Instead, the intention is to provide a foundational understanding that could inspire further research and experimentation in the tokenization of financial securities, particularly those that have yet to be explored.

5.1. Theoretical Model

The key players in this system are banks or financial institutions, acting as an intermediary, protection buyers, and protection sellers. The bank will assume a central role in the comprehensive ecosystem of CDSs contracts. In fact, through meticulous analysis and evaluation conducted by its market analyst, the bank exercises discretion in offering CDS contracts linked to specific underlying assets. Consequently, the protection buyer is afforded the opportunity to initiate the desired contract and negotiate terms solely within the parameters set forth by the bank.

Acting as a financial intermediary, the bank facilitates an efficient exchange of risk between buyers and sellers. Upon the purchase of a CDS contract, it is allocated to a designed pool, categorized as Low, Medium or High risk, reflecting the hypothetical default risk associated with the underlying asset. These pools serve the purpose of accumulating monthly contributions from all CDS participants, ensuring the viability of the contracts.

Notably, the realization of a CDS contract entails the bank making a final premium payment higher than the cumulative sum of monthly instalments. Conversely, in the absence of a default event, the protection funds contributed are consolidated within a centralized treasury accessible to the bank, which may freely withdraw necessary liquidity for potential reinvestment of capital.

Once an asset is selected, it is transferred to one of the three pools provided by the bank, categorized as high, medium, and low-risk pools. These pools represent the final return and the percentage that the protection buyer must pay. The smart contract linked to the token automates premium payments based on underlying assets. If the CDS contract is fulfilled, the bank will pay the final premium. However, in the case where the CDS contract is not realized, monthly shares will be transferred to a treasurer accessible to the bank for its operations.

To ensure effective risk management, CDS contracts with identical terms are grouped into standardized pools with similar characteristics such as duration, risk, exposure, and remuneration.

5.2. Blockchain Solution Definition

For this model, the blockchain that has been chosen is Hyperledger Besu. This solution is driven by several factors: Hyperledger Besu is an open-source system, ensuring the availability of source code and promoting transparency and accessibility and the project's strong credibility stems from the participation of reputable entities such as Public Mint Inc and other prominent banks [14], as well as its involvement in the European Blockchain Services Infrastructure (EBSI) project [15].

Hyperledger Besu offers the flexibility to be utilized in both private and public contexts. Although this solution currently focuses on a private framework, but it does not exclude the possibility of future expansion into a public network, considering the potential ease of transition.

The solution proposed derivates from a conventional staking model, where tokens are used on the platform to generate returns. The token is not transferable outside the platform where it holds validity, such as being unable to be sent to external wallets, and it will be managed through monitored accounts.

Hyperledger will serve as an interface to facilitate these operations. This model ensures high privacy standards in addition to operating within a private network. In terms of consensus, a Proof-of-Authority[16] (PoA) mechanism will be adopted. The proprietary nodes, represented by participating banks, will be involved in approving transactions related to derivative contracts (CDS) and will upload data to the private blockchain.

The token standard employed will be ERC20, representing a type of security token. The associated smart contract will manage functions and potential events, such as the token purchases with varying risk levels (low, medium, high).

The International Swaps and Derivatives Association (ISDA) acknowledges the importance of establishing a unified framework and standardizing Credit Default Swaps. ISDA has developed a framework that outlines various aspects and provides legal documentation specifying the necessary information and other elements to be included in such a contract [3]. These include:

- The referenced entity
- The maturity date (contract's expiration date)
- The notional value
- The premium
- The credit event trigger (the occurrence that would lead to the contract's liquidation)
- The procedure for liquidating the contract in the event of a credit event (to mitigate potential legal disputes)

According to these guidelines, the following key elements are proposed to ensure a comprehensive and standardized approach to Credit Default Swaps (CDS):

- **The referenced entity:** The system prompts users to provide an address under their control. This address is then securely recorded and relayed to the smart contract, where it serves as a unique identifier for the user, ensuring transparency and traceability throughout the contract lifecycle.
- **The insured amount:** Upon initiation of the contract, the underlying asset is fully collateralized and locked within the CDS smart contract. This is achieved through the issuance of a token, which represents the insured amount, thereby guaranteeing that the asset is protected and remains within the terms of the contract.
- **The premium frequency:** For operational efficiency, the system sets the premium payment frequency to every 30 days. This interval has been proposed to consolidate orders and facilitate the matching process, particularly given the current low volume of transactions expected, ensuring smoother contract execution and administration.

- **The premium:** This amount, once set, is managed by the smart contract to ensure that premium payments are made on time and in full during each 30-day payment cycle, thus maintaining contractual integrity and preventing disputes.
- **End of Contract:** The user is prompted to input the contract's maturity date via a date picker and the system ensures that the contract's timing is precise and consistent with the environment in which it operates.

5.3 Market Sizing and Competitive Landscape

The Total Addressable Market (TAM) by definition [17] *"represents the overall revenue opportunity available for a product or service if a 100% market share is attained"*.
In the context of this study, the TAM is considered to encompass the global population that possesses a bank account, as indicated by the Global Findex Database. According to this source, approximately 76% of the total adult population holds an account either at a bank or a similarly regulated deposit-taking financial institution [18].
The Service Addressable Market (SAM) addresses the question of which portion of the TAM is suitable for the product presented, specifically describing the market segment that can be effectively reached through the implementation of the proposed project.
In this scenario, a reasonable estimate can be derived by considering the total number of users who already possess digital assets. As previously mentioned, this figure stands at around 500 million individuals.
Furthermore, the Serviceable Obtainable Market (SOM) provides an estimation of the portion that the business can realistically serve. For this analysis, it is assumed that a credible estimate of the SOM would range between 1% and 2% of a bank's total customer base.
For what concerns the competitive landscape of blockchain-based CDS contracts there are both direct and indirect competitors operating.
Direct competitors include other blockchain platforms or companies that could offer similar CDS contract services. These competitors may provide comparable features, functionalities, and operability to the same customer base and would be built on different chains, specifically designed for creating and executing smart contracts.
On the other hand, indirect competitors encompass entities offering alternative solutions or financial instruments that address similar risk management needs as CDS contracts.

Although they may not be blockchain-based, they indirectly compete with customers seeking risk mitigation options.

Examples of indirect competitors in the CDS contract landscape include traditional financial institutions with established client relationships and regulatory frameworks, as well as centralized clearinghouses facilitating OTC derivatives trading.

It is important to note that the nature and intensity of competition can vary based on factors such as market penetration, regulatory environment, technological advancements, and customer preferences.

5.4 Mathematical Model

The bank plays a crucial role within the entire ecosystem as it analyses and evaluates market conditions to determine whether to offer a CDS contract for a specific underlying asset. The protection buyer, therefore, could initiate the desired contract and establish its maximum terms, but solely based on the bank's previous choices.

The bank also functions as a financial intermediary, facilitating efficient risk exchange between the buyer and seller.

Once the desired contract is purchased, it is directed to the specific pool (Low, Medium, High risk) designed to collect all CDS contracts with equal monthly premium payments to keep the contract alive.

The model described below serves as a general mechanism applied to each individual CDS contract entered by the protection buyer. The buyer has the discretion to determine a specific target, which represents the final premium that the bank will provide to the risk buyer, in the event of default on the underlying asset.

Conversely, if the CDS contract reaches its maturity without default or if the buyer decides to terminate it voluntarily, the monthly payments made to the protection seller are deposited into a treasury account (accessible exclusively by the bank, which can add or withdraw funds at any time).

In the case of early termination of the contract by the buyer, an additional monetary amount, a penalty, must be paid to minimize such occurrences and discourage excessive buyer reconsideration.

In the model presented, the penalty would be set at 20% of the remaining capital that the risk buyer would have to pay if the CDS contract were to continue until its actual maturity.

It is important to emphasize that obviously, the final premium granted by the bank in the

event of default on the underlying asset must be greater than the sum of the monthly payments that the buyer must make to keep the contract active.

This difference is computed using a predefined risk coefficient determined by the bank and subsequently applied to the granted final premium.

The formulas presented here are intended as a basic and simplified solution to the model. However, it is important to note that they would need to be further refined and complemented by more detailed, specific formulas. These additional calculations should be designed to meet the unique requirements and operational needs of each individual bank, ensuring that the model is customized and accurate for varying institutional contexts.

Total Capital Due from the protection buyer:

$C(i) = R(i) * T(i)$; with $i = l,m,h$ (Low, Medium, High Risk Pools)

where R = Monthly payment amount,

T = Total Duration of the CDS contract (expressed in months).

Low Risk Premium: $L = \frac{C(l)}{l}$; with l = (0,1).

where l = Risk coefficient assigned to ensure that L - $C_{(l)} > 0$.

Medium Risk Premium: $M = \frac{C(m)}{m}$; with m = (0,1).

where m = Risk coefficient assigned to ensure that M - $C_{(m)} > 0$.

High Risk Premium: $H = \frac{C(h)}{h}$; with h = (0,1).

where h = Risk coefficient assigned to ensure that H - $C_{(h)} > 0$.

Penalty: $P = \big(C(i) - R(i) * N(t)\big) * p$;

where $N_{(t)}$ = Number of payments already done,

p = penalty coefficient set at 0,2.

As a practical example, let's consider a given buyer A that wants to enter a low-risk CDS contract with a final premium L = \$10.000 in the case of a default event of a specific underlying asset. The total lifespan of the CDS contract is T = 36 months (3 years), and the risk coefficient is l = 0,9.

Therefore, the Total Capital Due that A must pay to keep the contract valid would be:

$C(l) = L * l$ ► \$10.000 * 0,9 = \$9.000.

And the monthly payment amount due from A is: $R(l) = \frac{C(l)}{T}$ ► \$9.000/36 = \$250/month.

Thus, A commits to making 36 monthly payments of 250€ each to receive a final premium of 10.000€ exclusively in the event of default on the underlying asset covered by the CDS. If A decides to end the contract after one year ($N_{(t)}$ = 12 months), the penalty due would be: $P = \big(C(l) - R(l) * N(t)\big) * p$ ► (\$9.000 - \$250 * 12) * 0,2 = \$1200.

CONCLUSION

This thesis highlights how asset tokenization is beginning to transform traditional markets by enhancing liquidity, transparency, and accessibility.

Real estate, art, and commodities sectors are leading the charge, as evidenced by several successful tokenization projects. However, the technology is still evolving, especially in areas like financial securities, where tokenization remains in the experimental phase.

The proposed model for tokenizing Credit Default Swaps offers a conceptual framework for further research, pointing to the untapped potential within this complex area.

As blockchain technology continues to develop and regulatory frameworks adapt to these innovations, tokenization is set to play a significant role in reshaping the future of global finance, paving the way for more efficient, secure, and inclusive markets across a wide range of asset classes.

ANNEX

1.: By definition: "**Blockchain** is a public ledger consisting of all transactions taken place across a peer-to-peer network. It is a data structure consisting of linked blocks of data, e.g. confirmed financial transactions with each block pointing/referring to the previous one forming a chain in linear and chronological order. This decentralised technology enables the participants of a peer-to-peer network to make transactions without the need of a trusted central authority and at the same time relying on cryptography to ensure the integrity of transactions." (European Union Agency for Cybersecurity). Below is shown how a blockchain works (Figure 17).

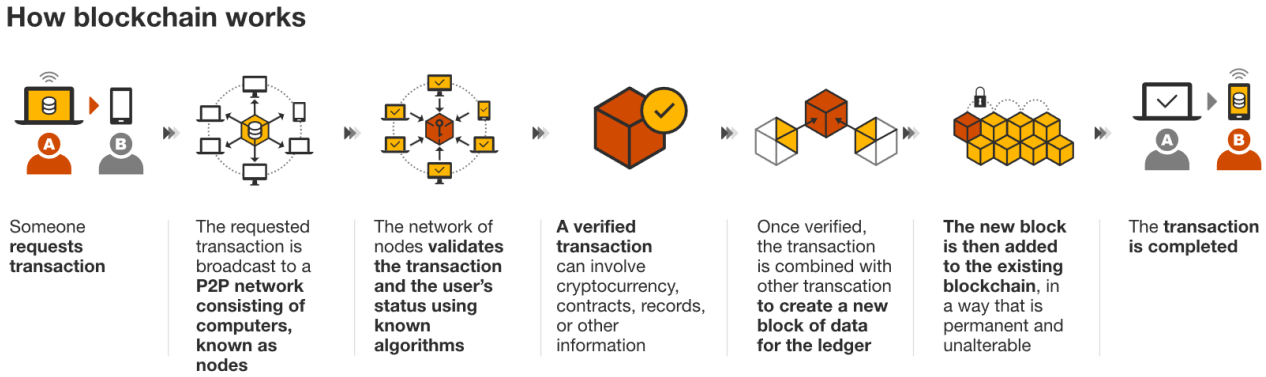

Figure 17: Description of a blockchain process (PwC, 2023).

2.: Bitcoin is a digital currency created for use in peer-to-peer online transactions. It is a decentralized system, meaning it operates independently of traditional financial institutions and governments. Bitcoin is based on cryptographic proof, relying on complex algorithms and protocols to secure and verify transactions, rather than trust in intermediaries.

3.: Ethereum is an open-source, distributed software platform based on blockchain technology. It has its own native cryptocurrency called Ether (ETH) and a programming language called Solidity that allows for the development of decentralized applications (dApps) and decentralized finance (DeFi) protocols.

4.: A **decentralized application** (dApp) is a type of distributed, open-source software application that runs on a peer-to-peer (P2P) blockchain network rather than on a single computer. dApps interact with blockchain-based "smart contracts," allowing them to operate autonomously without being controlled by a centralized entity.

5.: Decentralized finance (DeFi) is an emerging digital ecosystem that allows people to send, purchase, and exchange financial assets without relying on banks, brokerages, or exchanges. The blockchain mostly used to offer these financial services is the Ethereum one.

6.: A **Non-Fungible Token** (NFT) is a unique type of cryptographic token that represents a distinct digital or physical asset, such as a piece of art, digital content, or a video. It serves as an irrevocable certificate of ownership and authenticity, securely recorded on a blockchain. An NFT is a unique identifier that confirms the originality and authenticity of a specific asset. This ensures that no identical copy of the asset exists, and its ownership can be traced and verified on the blockchain.

7.: By definition: "The **compound annual growth rate** is the rate of return that an investment would need to have every year in order to grow from its beginning balance to its ending balance, over a given time interval. The CAGR assumes that any profits were reinvested at the end of each period of the investment's life span.".

CAGR formula: $CAGR = \left(\left(\frac{EV}{BV}\right)^{\frac{1}{n}} - 1\right) * 100;$

where: EV = Ending Value, BV = Beginning Value, *n* = number of years.

8.: A **stablecoin** is a type of cryptocurrency that maintains its value by being pegged to another asset, typically a traditional fiat currency such as the US dollar. For instance, a stablecoin linked to the US dollar is designed so that one unit of the stablecoin consistently holds a value equivalent to $1. However, there are different type of stablecoin (see Figure 18):

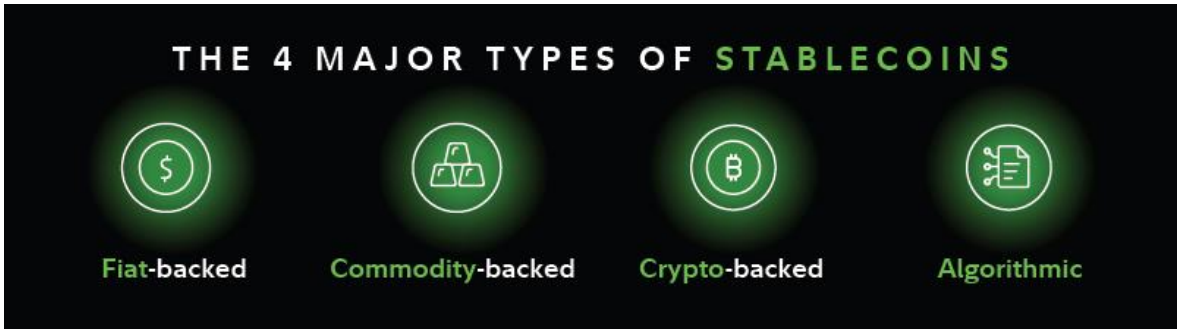

Figure 18: Types of stablecoins (Fidelity, 2023).

Fiat-backed stablecoins are pegged to the value of traditional fiat currencies and are issued by centralized entities. These companies maintain the stablecoin's value by holding reserves in the corresponding fiat currency (e.g. USDT by Tether, USDC by Circle).

Commodity-backed stablecoins operate similarly, but instead of being pegged to fiat currencies, they are linked to commodities such as gold.

Crypto-backed stablecoins, on the other hand, are backed by other cryptocurrencies and are typically issued by decentralized organizations or through smart contracts.

Algorithmic stablecoins, unlike the others, are generally uncollateralized and are managed by computer algorithms. To illustrate how this system works, consider an algorithmic stablecoin pegged to $1. If the price rises above $1, the algorithm generates additional coins to lower the value. Conversely, if the price drops below $1, the algorithm reduces the supply by removing coins from circulation to increase its price.

9.: Number of active **Ethereum users**: see Reference list 64.

10.: Number of active **Ethereum developers**: see Reference list 20.

11.: By definition: "**Smart contracts** are digital contracts that follows simple "if/when…then…" statements that are written into code on a blockchain that are automatically executed when predetermined terms and conditions are met. They are typically

used to automate the execution of an agreement so that all participants can be immediately certain of the outcome, without any intermediary's involvement or time loss. Smart contract can also automate a workflow, triggering the next action when predetermined conditions are met."

12.: RealT highlights: see Reference list 15.

13.: Last published report by Pax Gold, dated July 2024: see Reference list 50.

14.: See Reference list 29.

15.: See Reference list 19.

16.: By definition "The **Proof-Of-Authority** (**PoA**) is a consensus method that gives a small and designated number of blockchain actors the power to validate transactions or interactions with the network and to update its distributed registry."

17.: See Reference list 63.

18.: See Reference list 30.

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