

Will tokenization change the way we understand fine wine?

Theoretical layout and future prospects

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Abstract

The role of fine wine as an alternative investment has been in recent times subject to increasing academic interest. Wine investment, albeit being a principled option in different types of portfolios, presents a set of barriers and limitations that hinder its overall performance. This paper explores fine wine tokenization – representing fine wine through blockchain tokens – as an alternative to the current model where investing mainly takes place in auction houses and wine exchanges or funds. Ever since 2021, a still small but growing amount of initiatives have explored tokenization in the fine wine sector, yet it is early to talk about any form of widespread adoption. We aim to lay down the theoretical framework behind tokenization and analyze the dynamics emerging from current fine wine token collections. We propose winery-based tokenization as a promising disruption in the fine wine market, where an uncertain legal framework, technical restraints and information asymmetries could entail short-term challenges meriting further research efforts.

Keywords: Wine, blockchain, tokenization, NFT, alternative asset

I. Introduction

The past decades have seen a growing interest in the study of fine wine as an alternative asset. Its high returns and potential diversification benefits (Aytaç et al., 2016; Bouri et al., 2018; Faye et al., 2015; Le Fur & Outreville, 2019) have supported the argument that fine wine is a viable investment. To invest in fine wine, auction houses, wine brokers or wine funds such as the Liv-ex constitute the main available choices. Other market components, namely specialised warehouses, complete the picture, providing trust and security in handling the storage of fine wines. Trading wine incurs additional costs as these aforementioned businesses and their commissions are paradigmatic to the current market structure. Transactions can take long and information asymmetries (Onur et al., 2020), coupled with the uncertainty of wine's vintage effect (Hekimoglu et al., 2016;

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Storchmann, 2012), constitute barriers to entry for newcomers who may not have the required knowledge to navigate the wine market. It is also debatable whether fine wine returns are a product of currency risk and liquidity risk (Masset et al., 2021; Maurer et al., 2020), as fine wine has become a globally traded asset and it often lags a couple of months behind the general market trends.

The adoption of blockchain technology within the business world could prove useful in overcoming some of these limitations. Blockchain was born in 2008 when pseudonymous author Satoshi Nakamoto published the Bitcoin whitepaper (Nakamoto, 2008). Bitcoin is a digital payment system where all entries and events go through a distributed ledger called blockchain. Blockchain records are verified through a consensus mechanism and, once included, information is immutable (Crosby et al. 2016). Bitcoin as a network, polarizing opinions aside, has remained successful in updating the ledger every ten minutes in a secure way. The decentralized, transparent and immutable nature of blockchain has triggered a technological revolution, allowing for the foundation of new solutions and applications within the digital economy (Xu et al., 2019).

The main downside of Bitcoin in terms of functionality was that its base blockchain layer could not host more complex applications besides simple transactions. As an answer, Ethereum, another decentralized open-source blockchain, was launched in 2014. The main innovation behind Ethereum was its capacity to run smart contracts (Zheng et al., 2020) written in Solidity, a Turing Complete programming language,² and then compiled into the Ethereum Virtual Machine.³ Smart contracts are a set of self-executable rules whose complexity may vary from simple examples such as the functioning of a vending machine to Decentralized Autonomous Organizations or DAOs.⁴ Smart contracts open a realm of new possibilities, where decentralized applications are being built in areas such as finance, logistics or videogames.

In this paper, we examine the implications that arise from understanding fine wine as a tokenized asset. Asset tokenization consists in representing ownership of a physical asset

² Turing completeness refers to the capability of a programming language to be able to hypothetically match the computing power of a Universal Turing Machine (Jansen et al., 2019).

³ The Ethereum Virtual Machine is a decentralised supercomputer that compiles and executes the smart contracts recorded within the Ethereum blockchain (Buterin, 2014).

⁴ A Decentralised Autonomous Organization is a smart-contract-based organization without a central authority where members can decide upon its governance through voting and proposals (Wang et al., 2019).

as a tradable digital entry within a blockchain. We want to delve into the potential adoption of this novel concept while determining the future challenges that could hinder the development of tokenized wine solutions. The article will be divided into three main different segments, them being: **II. Asset tokenization**, describing the broader phenomena and applications; **III. Fine wine tokenization**, examining the potential benefits of wine-backed tokens and current applications; and **IV. Challenges to wine tokenization**, addressing the legal framework, technical limitations and information asymmetries. The **Conclusion (V)** draws into what we should expect out of the notion of wine-backed tokens as an alternative investment.

II. Asset tokenization

Blockchain or blockchain technology refers to a cryptographically based distributed ledger system, where transactions between network actors are stored in a linear, secure and immutable fashion (Rishius & Spohrer, 2017). Blockchain receives its name because new data entries are put into blocks that are “chained”,⁵ forming a whole ledger representing the transaction history. The aforementioned network actors are called nodes, and they keep, update and validate the event log of the ledger in a consensual way. This consensus is reached thanks to different types of algorithms, being the most extended Proof of Work (PoW, used in like Bitcoin or Ethereum), where nodes verify and validate transactions by solving complex hash puzzles that require high computational power; and Proof of Stake (PoS, being examples blockchain projects like Cardano or Tezos), where nodes secure the blockchain based on the number of network coins that they hold (Mingxiao et al., 2017). Consensus algorithms are designed to disincentivize behaviours that could threaten the integrity of the record of transactions, by making tampering prohibitively expensive in terms of workload (PoW) or coin value (PoS).⁶

⁵ Blocks contain, besides their own hash, timestamp and nonce, the hash value of the previous block, causing that if past block information were to be modified that block hash and the subsequent ones would change. Network participants will take notice of the altered log event comparing it to the non-tampered, consensually reached blockchain (Nofer et al, 2017).

⁶ Out of the possible attacks on blockchain applications, the main one relating to consensus is the majority attack, also known as the 51% attack. Single nodes or a group of rogue nodes controlling the majority of network hash (or staked funds in PoS) can, during that time, prevent transaction verification, reverse transactions or split the network (Saad et al., 2020). 51% attacks are realistic against smaller market capitalisation networks where, depending on the consensus algorithm, enough hash rate or staked funds are in practice attainable, but not necessarily profitable.

Bitcoin, being the precursor of blockchain, cannot, on its base layer, record events of greater complexity than simple transactions. The arrival of Ethereum and other second-generation blockchains brought the figure of the smart contract, a set of rules of varying complexity that take advantage of the decentralized nature of blockchain. Smart contracts are scripts that allow for agreements between network actors without the need for a trusted third party, as they can automatically execute once a set of specific conditions are met (Alharby & van Moorsel, 2017). Smart contracts have been applied to a broad range of areas, namely Internet of Things (IoT), distributed system security, finance, data provenance, sharing economy and public sector (Zheng et al., 2020). Recent developments are also being aimed at topics like Decentralized Finance (DeFi), consisting in the decentralized provision of financial services through smart contracts (Zetsche et al., 2020); the “metaverse”, combining technologies like virtual reality, blockchain and digital twins to build a parallel digital universe (Gadekallu et al., 2022); and DAOs, exploring novel forms of corporate governance through the implementation of smart contracts (Blemus & Guegan, 2019; Wang et al., 2019). Conversely, smart contracts are not technically flawless, as factors like code security, inefficient debugging tools, challenging characteristics of underlying programming languages, gas fees and lack of solid development resources constitute limitations to be addressed (Zou et al., 2021). These elements do not deter an ever-increasing research interest in the potential economic benefits of blockchain and smart contracts (Xu et al., 2019).

Alongside smart contracts, the other figure that enables new promising applications within blockchain networks are tokens. Tokens could be described as digital units stated as blockchain entries that can represent something of value (Oliveira et al., 2018). Token classification can be subject to a wide range of different parameters, each with its attributes that will affect how we describe the dynamics behind tokens. The most general of the parameters is the class, where we differentiate three types of tokens. Blockchain base layer tokens (BTC, ETH), also referred as digital money (or e-money), constitute an economic incentive for transaction validation and represent a “share” of the network, being employed to pay for gas fees and act as currency. Utility tokens can, within a protocol or network, grant certain rights such as the ability to vote on proposals. Thirdly, token securities can represent digital shares. Another classification for tokens of increasing relevance is the dichotomy between fungible and non-fungible tokens. Fungible tokens are identical, interchangeable and divisible, thus implying equal value

between same types (Popescu, 2021). Fungible tokens were the first type of cryptographic tokens to initially appear, as blockchain base layer tokens are technically fungible. Their counterpart, Non-Fungible Tokens (NFTs), represent ownership of digital or physical assets⁷ whose distinct characteristics render them unique. NFTs have gained mass attention due to the staggering prices that certain ones representing digital assets have commanded.⁸ The potential of NFTs lies in key properties arising from their decentralized nature, such as ownership verifiability, transparent execution, uninterrupted availability, usability or tradability (Wang et al., 2021). Fields related to the digital sphere that are actively exploring NFT adoption are the gaming industry, virtual events, digital collectibles/intellectual property collection and metaverse virtual economy.

Promising applications related to tokens⁹ are not limited to digital domains, and the concept which could tackle the fine wine industry is the tokenization of physical assets. In tokenizing physical assets, their subsequent value can be effectively digitized and managed as a virtual asset (Freni et al., 2020). The token acts as a vehicle that represents proof of ownership while benefiting from being understood as a unit of account within a blockchain. Tokenization is one of the pillars behind the broader notion of the so-called token economy, defined as the decentralized economy and novel business models emerging from being able to transfer ownership of assets (both digital and physical) through tokens (Lee, 2019; Sunyaev et al., 2021). Tokenization related to fine wine is not to be mistaken with security tokenization which deals with the tokenization of investable infrastructure assets that generate a cash flow and consequently are expected to comply with existing security law (Tian et al., 2020). The remainder of this paper focuses on non-security tokenization, as wine-backed tokens currently fall outside the definition of security tokens, and neither e-money nor utility tokens, delving into the current legal status of wine tokens in Section IV.

⁷ Tokens can also represent intangibles such as IDs, education credentials, driver's licenses and voting rights.

⁸ Notorious examples are digital artist Beeple's *EVERYDAYS: THE FIRST 5000 DAYS*, NFT of a collage of 5,000 of his earlier artworks sold at Christie's for \$69.3 million; digital artist Pak's creations such as *Clock* or *HUMAN ONE*, sold for \$52.7 and \$28.9 million, respectively; or NFTs from prominent collections like CryptoPunks, where rare CryptoPunks have been traded for as high as \$23.7 million (Graves et al., 2022).

⁹ From now on, token will be the preferred term over NFT when addressing broader phenomena, as it is a more versatile concept to refer to the unit of account that will represent the wine. NFT will be in most occasions interchangeable with token and employed when specificity is required.

Among physical assets, real estate and art are areas where tokenization could pose potential benefits to help address current limitations. The real estate market is characterised by high initial buying costs, low liquidity, the requirement of a trustworthy tenant to earn rental income, numerous needs intermediaries and high transaction costs (Gupta et al., 2020). The real estate tokenization concept, involving single properties or a portfolio of properties, could leverage on factors fractionalization of ownership, liquidity management through partial tokenization, the inclusion of lower-income individuals, global offering, lower-cost faster transactions, diversification of smaller portfolios, transparency and programmability (Kasprzak, 2021). Aforementioned points, including pooling properties together or fractionalization of ownership, condition tokens backed by real estate to be considered as security tokens. Respecting physical art, tokenization offers promising prospects linked to provenance and authentication, fractional ownership, royalties, digital scarcity and financialization of art (Whitaker, 2019). Tokenizing art could empower the figure of the own artist or artist's study as a producer offering individuals direct exposure to art investment. Challenges for tokenization in both real estate and physical art are associated with the technical constraints of blockchain and loose regulatory frameworks. Segments III and IV will go into detail on the opportunities and limitations arising from wine tokenization.

III. Wine tokenization

Investment-grade wine constitutes one of the possible use cases of asset tokenization. Understanding wine property as a tradeable entry within a blockchain has the potential to overcome some of the current limitations that characterise the wine investing market. Recently, certain firms have tried to implement this possibility, but as we will see functionality is limited and these efforts constitute both an initial approach to asset tokenization and an attempt to capitalise on the NFT boom. Current academic publications are almost non-existent for the phenomena of wine tokenization, thus this constitutes our best effort to approach the topic through grey literature and on-chain data to lay out the relevant cues to future work.

A) Potential benefits of tokenization

The tokenization of fine wine theoretically offers some advantages that could help ease the current market frictions. Heines et al (2021) present six different drivers of asset

tokenization, which to a different extent can also be applied to the case of wine. These drivers include democratization, increased liquidity, disintermediation, increased transparency, process optimization and digital scarcity. Wine tokenization could have the following implications:

- ***Democratization*** of the fine wine investment market, as tokenization could remove current barriers of entry for retail investors. Not only the process of trading fine wine is rather tedious, but access to certain distribution channels requires knowledge and associated fees. Wine-backed tokens can be traded in secondary global markets like OpenSea¹⁰ which are free to enter. Average investors would enjoy equal access to investment opportunities, and tokens – backed by wine – could be issued and traded anytime, anywhere (Chen, 2018). Iconic wines could also be potentially fractionalized into smaller units, which could permit retail investors to partially own high-end references. Fractionalization of wine has in any case its shortcomings, as it could fall in the security token classification and it is at the expense of the claim of drinking that wine, an event that is mostly tied to complete ownership.
- ***Increased liquidity*** of an illiquid asset such as wine thanks to cheaper, faster transactions, taking place in easier-to-access decentralized marketplaces. A larger trading volume could also potentially be reached as NFT investors (who can have no prior experience with wine investment) might also be attracted to wine tokens.
- ***Disintermediation*** will be a factor in the case of wineries deciding to directly tokenize some of their wines and take care of storage. The need for trusted intermediaries will be reduced and could be contemplated in case of physical space requirements. Investors could acquire fine wine as tokens that could be later traded peer-to-peer without the need of relying on auction houses, wine funds or wine brokers. This could affect the current business model of some of these market actors, who in contrast could embrace the winery-based tokenization phenomena and offer, in exchange for intermediation, more refined investment options while ensuring correct operability (Abbatemarco et al., 2020). These investment options may also include minting tokens backed by wines that they already offer to trade.

¹⁰ OpenSea is the largest NFT and crypto collectibles marketplace; accessing and navigating the platform is free, as well as minting NFTs. Trades incur a 2.5% seller fee.

Private investors will be able to theoretically tokenize their collections, but challenges arise related to provenance and wine redemption.

- ***Increased transparency*** could be one of the most relevant drivers behind fine wine tokenization. Counterfeit of highly demanded iconic wines has been in the past years on the rise and it constitutes an ever-present risk. Wine provenance is also important, as inadequate wine storage conditions can turn sour both the content and price quotation of a wine. Wine tokenization offers traceability of token ownership, but could also include information related to the physical state of the bottles. This would require the implementation of a wine supply chain traceability system based on blockchain, where combining IoT and QR codes or NFC tags data could be captured and the status of the bottle updated (Biswas et al., 2017; Cakic et al., 2021) as if in the case of implementing a blockchain-based traceability system).

- ***Process optimization*** is a point that not only can be applied to the investment and trade of bottled fine wine but also to access financial products using wine as collateral. Fine wine tokens, as they are backed by bottles whose downward price potential is typically limited, could be attractive collateral for loans provided by Decentralized Finance applications. Currently, digital art NFTs are increasingly being accepted as collateral for loans in DeFi (Mazur, 2021), being more volatile collateral than wine. Tokenization could develop into the financialization of wine, thanks to newer ways of monetizing and liquidating the underlying asset.

- ***Digital scarcity*** may not be the main driver that justifies the adoption of tokenization in wine investment, but a set of dynamics arise from this concept that are worth noting. If fine wine tokenization were to become a successful standard within the industry, the digital property could be understood separately from the physical property in terms of scarcity. How valuable could the first tokenized vintage from a highly admired producer be compared to the ones that will follow? The subjective desire for the digital token backed by the physical wine could be greater than the physical wine alone. Transparency of the transaction record and uniqueness of the tokens can also imply that in case the identity of a famous figure gets leaked as the owner of a wine-token holding wallet, the associated wine tokens could drive up in value. In the context of the digital economy, these

examples can in practice act as limited editions and thanks to blockchain reinforce the notions of scarcity, originality and authenticity (O'Dwyer, 2020).

Given the aforementioned drivers, we suggest that future potential benefits of wine tokenization will most likely materialize through wineries adopting and advocating for this standard. Wineries, as the creators behind these wines, have the credibility required to ensure the correct custody of tokenized bottles. As tokens are a digital representation of a physical asset, wineries give maximum assurance of the physical integrity of each wine. Wineries can also offer the option to burn the token in exchange for redeeming the wine to a physical address, increasing investors' choice, or implementing royalties associated with the exchange of wine-backed tokens in the secondary market. Other concepts, such as fractionalization and especially financialization of wines may apply, offering new tools to broaden the opportunities in the wine investment market. Investors will be able to trade their tokens in decentralized global markets where conditions related to cost and speed of transactions are better than when operating via wine funds, brokers or auction houses. A model of winery-based tokenization can result in new ways to interact between fine wine producers and their potential customers while taking a step forward in the overall process of digital transformation.

B) Current state of tokenized-wine solutions

In 2021, the NFT market hit the mania stage and some big producers decided to capitalize on this trend and launched various collections of wine tokens. The tokenization of fine wine is in its infancy, and being wine a sector where changes often take time to fully develop it would be unlikely for this phenomenon to be widely adopted in the short term. In this section, we analyze using on-chain data how the different proposals have fared in the secondary market and whether tokenization is delivering its promised advantages.

The main household names that decided to launch NFT-backed wine are Penfolds, Robert Mondavi, Dom Pérignon and Château Angélu. Penfolds partnered with BlockBar (Penfolds, 2022), a platform that offers tokens backed by bottles from premium liquor brands. So far, three different NFT collections have been released: a 225 litter barrel of Penfolds Magill Cellar 3 2021, 300 bottles (each one a different token) of Penfolds Magill Cellar 3 2018 and two different 2018 blends of Cabernet-Shiraz in a 6-litter format. Wines represented by tokens are tradable and can be redeemable from a certain date; both BlockBar and Penfolds ensure that tokens are backed by the real asset. Robert Mondavi

released a collaboration with French porcelain house Bernardaud to create 1,966 Magnum bottles of Limoges porcelain where a piece of algorithmically generated digital art is linked to the token (Robert Mondavi Winery, 2022). Mondavi does not plan on allowing for long-term holding of these tokens, as wines will be claimable for delivery between October and December 2022. Unclaimed bottles will be delivered to the purchaser's address that was required at the moment of acquiring the token. Dom Pérignon is another renowned producer that launched fifty bottles of its 2010 vintage and another fifty of the 2006 vintage of its Rosé champagne in a collaboration with Lady Gaga as a digital NFT (Billard, 2021), but physical bottles were delivered to buyers and the tokens at present can only be considered as digital art. Château Angélus partnered with UK-based investment and management company Cult Wines to tokenize a barrel of its 2020 vintage, including in the NFT a digital animation of the iconic Angélus bell that sold for \$110,000 (Mercer, 2021).¹¹ Besides wine, most of the current tokens that are minted by wineries also bundle in some type of in-house experiences, such as winemaker tastings or vineyard tours, or a piece of digital art.

Auction houses, such as Strauss & Co, are also experimenting with tokenized wine events. April 2022 saw the holding of an auction where five iconic South African estates bundled vertical collections of Klein Constantia Vin de Constance, Kanonkop Paul Sauer, Meerlust Rubicon, Mullineux Olerasay and Vilafonté Series C each into a single token (Strauss & Co, 2022). Another ambitious newly-created platform that seeks to offer tokenized wine as an investment alternative is WiV Technology. WiV Technology offers, besides metaverse solutions and utility tokens of its platform, curated NFTs allegedly backed by physical wine coming from trusted custodians. Its OpenSea marketplace offers household names including Chateau D'Yquem, Dom Pérignon, Krug, Louis Roederer, Antinori, Tignanello or Vega Sicilia. On the downside, token burn and redemption of the wines are not yet available and custodian partners are not publicly known, raising doubts about the backing of the tokens.

Out of the different fine wine token releases, only two have seen reasonable trading activity in the secondary market: Mondavi and Penfolds Magill Cellar 3. Regarding the two other Penfolds releases, the 225 litter barrel of Penfolds Magill Cellar 2021 was sold

¹¹ The token can be checked in OpenSea, no activity has taken place since August 2021. <https://opensea.io/assets/ethereum/0x495f947276749ce646f68ac8c248420045cb7b5e/12031231455788111425644087349086769384757347738502174220177251521673266462721>

for approximately \$130,000 and both the Imperial Cabernet-Shiraz blends for around \$28,000 each, but none have seen further trades. Dom Pérignon tokens have also been traded – up to 55 trades – in the secondary market, but as wine was initially physically delivered to buyers they cannot be considered backed by wine and are just pieces of digital art. WiV Legacy Collection has seen 60 trades ever since December 2021,¹² but most can be attributed to direct sale tokens by WiV and not peer-to-peer trading.

Robert Mondavi started offering in December 2021 a direct sale of 1,966 porcelain Magnum bottles for \$3,500 per token, but the whole release has not been sold out yet. As of July 2022, out of the initial launch, only 639 tokens have been minted by Robert Mondavi's Ethereum address. Table 1 reflects how some of these NFTs have seen trading activity in the secondary market, accounting for 66 total trades, and a total volume of \$98,202.94 (35.76 ETH).¹³ The maximum price of a traded token was \$5,344.66 and the minimum price was \$549.68. Table 2 includes the average (\$1,722.85) and median price (\$1750.35), both sitting at around half the direct sale quotation. All trades have been executed using ETH (the native cryptocurrency of the Ethereum network), which has heavily conditioned price movements. The correlation between the token price and the ETH/USD quotation is 0.6472, raising to 0.7238 if outliers are excluded.

In the case of Penfolds, its 300 bottles of Penfolds Magill Cellar 3 2018 quickly sold out the entire collection on the release date – January 18th 2022 – for \$481.84 (0.15 ETH). Table 1 reflects that 66 trades have followed since in the secondary market,¹⁴ with prices ranging from \$1581.93 to \$192.24. The average token price (Table 2) sits at \$629.27 and the median price is \$603.00. As in the case of Mondavi wines, trades were quoted in ETH, and the correlation between Penfolds token price and ETH price is worth noting at 0.5728 and 0.6815 if three trades that can be considered outliers (see Figure 2) are excluded. In both Mondavi and Penfolds correlation values (including and excluding potential outliers), p-values are under 0.001. On-chain data indicates that Ethereum price has played a substantial in the USD value of Mondavi and Penfolds wine-backed tokens.

¹² As of July 2022, the total volume traded sits at 16.1 ETH, accounting for \$46,698.

¹³ <https://opensea.io/collection/wiv-legacy-collection>

¹⁴ <https://opensea.io/collection/rmw/activity>

¹⁴ Secondary market sales of just Penfolds wines can be easily accessed through BlockBar's transaction record. <https://blockbar.com/brands/Penfolds>

Table 1. Minted tokens, total volume, maximum and minimum price (as of July 2022).

| Collection | Minted Tokens | Total Volume (ETH) | Total Volume (USD) | Number of Trades | Max. Price (ETH) | Max. Price (USD) | Min. Price (ETH) | Min. Price (USD) | Max. Price Date (USD) | Min. Price Date (USD) |
|--|------------------|-----------------------|-----------------------|---------------------|---------------------|---------------------|---------------------|---------------------|--------------------------|--------------------------|
| Robert Mondavi x Bernardaud | 639 | 35.76 | 98202.94 | 57 | 1.5 | 5344.66* | 0.3649 | 549.68** | 12/17/2021 | 06/30/2022 |
| Penfolds Magill Cellar 3 2018 | 300 | 16.38 | 41532.01 | 66 | 0.5 | 1581.93 | 0.15 | 192.24** | 01/19/2022 | 06/17/2022 |

* Maximum Price in USD corresponds to a different operation than the Maximum Price in ETH.

** Minimum Price in USD corresponds to a different operation than the Minimum Price in ETH.

Table 2. Launch price, average price, median price, standard deviation and correlation between the trade price and ETH price.

| Collection | Launch Price (USD) | Avg. Price (ETH) | Average Price (USD) | Median Price (USD) | Standard Deviation | Correlation (Price in USD; ETH/USD) | p-value |
|--|-----------------------|-----------------------|---------------------------|---------------------------|-------------------------|--|--|
| Robert Mondavi x Bernardaud | 3500.00 | 0.627 0.614 | 1722.85 1658.18 | 1750.35 1738.06 | 741.13 566.28 | 0.6472 0.7238 | $5.73 \cdot 10^{-8}$ $2.93 \cdot 10^{-10}$ |
| Penfolds Magill Cellar 3 2018 | 481.84 | 0.248 0.236 | 629.27 586.21 | 603.00 588.10 | 372.24 176.62 | 0.5728 0.6815 | $5.02 \cdot 10^{-07}$ $7.87 \cdot 10^{-10}$ |

Note: **Bold** corresponds to values excluding outliers (red dots in Figures 1 and 2)

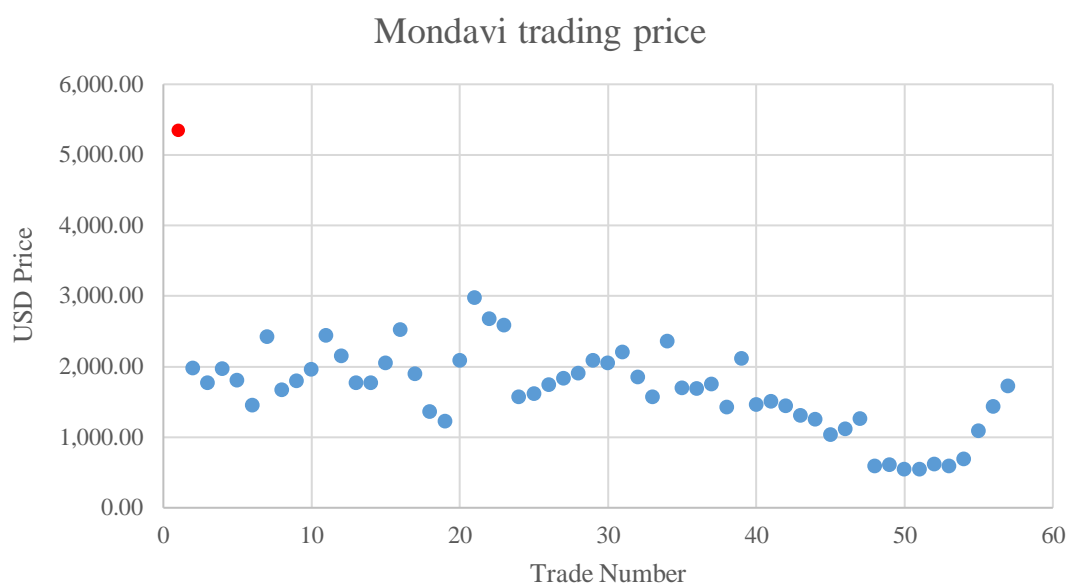


Figure 1. Robert Mondavi x Bernardaud total trades.

Note: Prices are displayed in USD, trades were originally executed in ETH. The opening price of the ETH/USD pair was taken to carry out the conversion on any given date.¹⁵

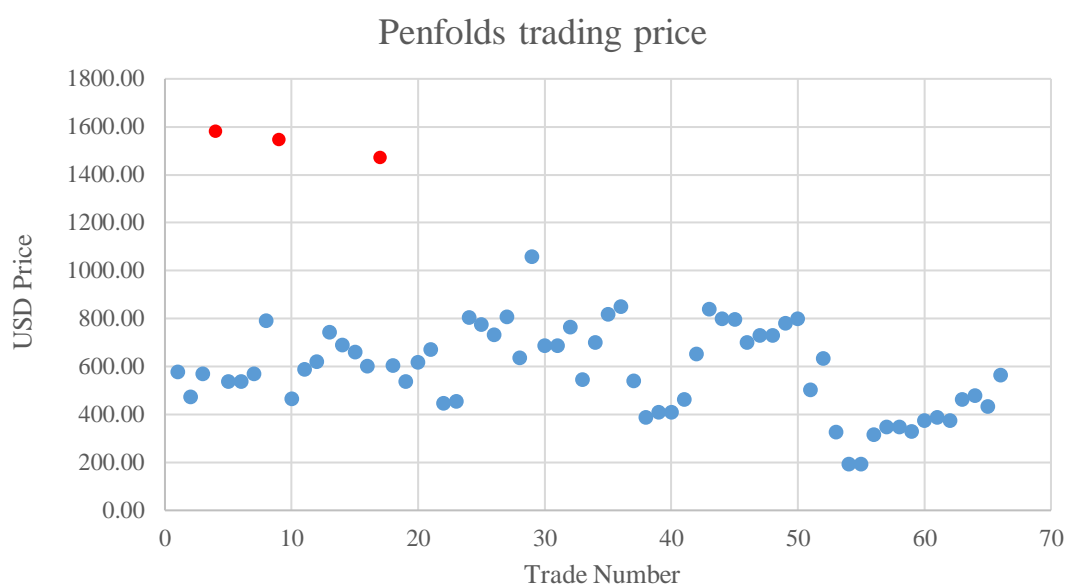


Figure 2. Penfolds Magill Cellar 3 2018 total trades.

Note: Prices are displayed in USD, trades were originally executed in ETH. The opening price of the ETH/USD pair was taken to carry out the conversion on any given date.

¹⁵ The opening price of the ETH/USD pair (which just constitutes a fixed daily time, as the cryptocurrency market does not open nor close) was extracted from CoinMarketCap. <https://coinmarketcap.com/es/currencies/ethereum/historical-data/>

Figure 1 and Figure 2 illustrate the price quotations on all trades ordered chronologically. Compared to its release price, Penfolds has fared much better than Mondavi, where the average trade price is half of the release price. Only one trade of Mondavi x Bernardaud, which can be considered an outlier, had a price over the \$3,500 mark. Regarding Penfolds price quotations, three different trades over \$1,400 can be considered outliers. Token price/ETH price correlation could be even greater if these values were to be ignored. It is worth noting that ETH prices have moved from over \$4,800 in November 2021 to below \$1,000 in June 2022, and minimum prices of both types of wine-backed tokens hit their lows in June.

This significant correlation is a factor that investors should be conscientious about, as it is a product of both liquidity and exchange risk. When listing a token at a certain price, said quotation can remain unchanged for months when the sale does not occur due to low liquidity. In the meantime, if the wine token is listed in a cryptocurrency like ETH, the exchange rate in USD, EUR, or GBP can vary dramatically. This can generate scenarios where wine-backed tokens are severely undervalued compared to trading prices through current wine funds or brokers. Image 1 is an example coming from the WiV Legacy

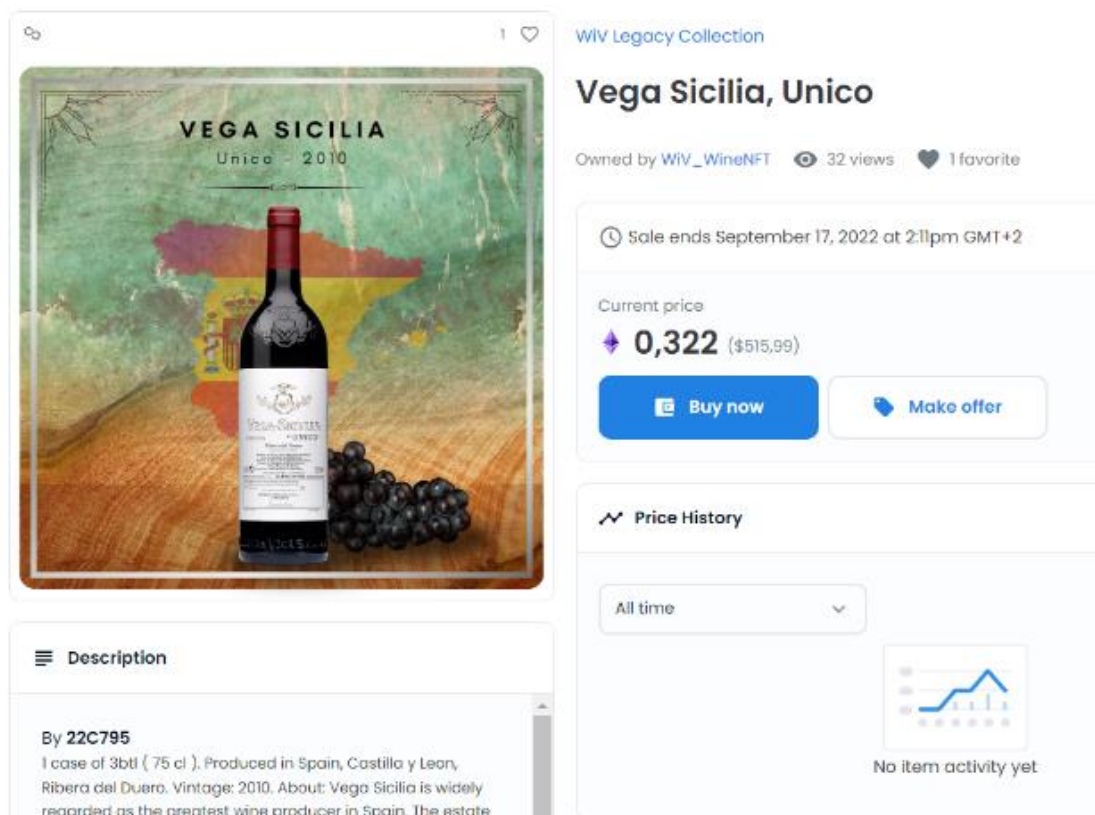


Image 1. 2010 Vega Sicilia Único, WiV Legacy Collection.

Source: OpenSea. <https://opensea.io/assets/matic/0x57a8d59eff06381a9b0d709271871187ee1b418c/84>

Collection, specifically of a token representing a 3-bottle case 2010 Vega Sicilia Único. As of July 2022, this token has been listed at 0.322 ETH since March 17th. In the meantime, the USD value of 0.322 ETH has been as high as \$1,150.82 (@ 3,573.96 \$/ETH on the 3rd of April, 2022) and as low as \$288.55 (@ 896.11 \$/ETH on June 18th, 2022). Único 2010 is currently been traded at the Liv-ex for approximately £2850 per 12-bottle case, which amounts to \$850 per 3-bottle case. Throughout parts of June and July, when ETH price has been hovering around the \$1,000 mark, this token has been trading at a large discount. Ideally, investors would list their tokens in stablecoins such as USDC or DAI, to avoid risks associated with the volatility of cryptocurrencies.

Alongside the limited secondary market liquidity of fine wine-backed tokens, the rest of the aforementioned benefits of tokenization are out of reach of the current efforts. The democratization of fine wine investment is unclear, as either wine redemption is compulsory (not allowing for long-term investment) or cases such as Penfolds suffer from relatively high fees (BlockBar charges a 10% seller fee). Accessibility is a variable to be considered, as trading in decentralized markets such as OpenSea is not overly complex but requires minimum knowledge of how to set up a wallet and acquire ETH or any given cryptocurrency to operate. Disintermediation is variable, Penfolds or Angélus examples of wineries partnering up with third parties (BlockBar and Cult Wines respectively) and WiV Technology an intermediary that purportedly tokenizes wine coming from trusted custodians. Transparency can only apply to token ownership and not wine provenance, even though the sector is actively developing solutions to ensure authenticity and combat counterfeits. The impact of process optimization thanks to concepts such as financialization or fractionalization is minimum, and the current main driver for winery adoption seems to be digital scarcity, apparently inspired by .jpg NFTs, as some collections included pieces of digital art.

IV. Challenges to wine tokenization

Wine tokenization faces challenges from three different areas that may hinder its adoption. The first is the legal sphere, where regulatory uncertainty and lack of a clear framework regarding asset tokenization, coupled with KYC requirements, will be topics that sector members should contemplate when deciding if implementing a solution revolving around tokenization. The second aspect concerns the technical intricacies behind blockchain technology, where notions related to the blockchain of choice and

future interoperability have to be analyzed. Lastly, the third area deals with the moral hazard arising from malevolent but plausible behaviours such as creating artificial supply – tokens not backed by wine – or employing the traceable nature of the token and the digital property that it represents to derive it as a proxy of immaculate physical provenance.

A) Legal framework

Innovation in the digital asset sphere has thrived over the past years, developing at such speed that the legal framework has yet to update accordingly to effectively cover all the different novel concepts. In the European Union, the European Parliament and Council have, on June 30th 2022, reached a provisional agreement on the Markets in Crypto-Assets regulation (*MiCA*),¹⁶ initially introduced as a proposal in 2020. Even though a wide variety of crypto-assets, primarily asset-referenced tokens,¹⁷ e-money tokens¹⁸ and utility tokens¹⁹ and fall under the scope of *MiCA*, it does not fully apply to NFTs. Only in the case of tokenized asset collections, a figure that could be applied to wine, *MiCA* will require that the underlying company provides a whitepaper explaining both the product and how it interacts with the blockchain. Nonetheless, it is expected that future review clauses shape a specific regulatory regime. In the US, the Securities and Exchange Commission (SEC) is closely tracking developments concerning digital assets, and further future legislative and regulatory efforts will likely follow during the next years. The SEC has in the past addressed certain crypto assets as securities, being NFTs not currently directly regulated and depending on a variety of factors to classify it as a security or not. In the case of wine-backed tokens, as in the EU, it seems unlikely that current US regulations will acknowledge them as securities. Conversely, international consensus about whether to embrace crypto assets as a whole is not uniform, as countries like China have adopted opposing official stances, carrying regulatory efforts and imposing severe restrictions. The environmental impact of blockchain-based solutions may also be subject

¹⁶ Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on Markets in Crypto-assets, and amending Directive (EU) 2019/1937.

¹⁷ “(...) type of crypto-asset that purports to maintain a stable value by referring to the value of several fiat currencies that are legal tender, one or several commodities or one or several crypto-assets, or a combination of such assets” (*MiCA*, Article 3, 1.3.).

¹⁸ “(...) type of crypto-asset the main purpose of which is to be used as a means of exchange and that purports to maintain a stable value by referring to the value of a fiat currency that is legal tender” (*MiCA*, Article 3, 1.4.).

¹⁹ “(...) type of crypto-asset which is intended to provide digital access to a good or service, available on DLT, and is only accepted by the issuer of that token” (*MiCA*, Article 3, 1.5.).

to future regulation, even though currently the most prominent blockchain networks with smart contract capabilities are based on less power-hungry consensus algorithms like Proof of Stake.²⁰

One of the figures that will benefit from a robust framework to avoid legal issues is the ownership right represented by the token. Definitive regulation recognizing the ownership of the underlying asset behind a token through owning said token is not yet a reality. Consequently, trust in the figure in charge of the tokenization of the wines is key to ensuring the rights of the physical asset. Tokenization where wineries play the main role, like in the case of Penfolds, Robert Mondavi or Dom Pérignon is currently the principled option to certify that tokens are rightfully backed by their physical counterparts and that redemption is available. Adequate storage conditions should be guaranteed, and further integration of sensor readings – guaranteeing change in physical status concerning the tangible asset – could broaden the sphere of trust beyond winery boundaries including trusted supply chain partners (Sunyaev et al., 2021). Concerning ownership, KYC has to be contemplated as, up until redemption of the underlying asset, actors behind tokenization would be acting as custodians of said asset. KYC process can be both centralized (through the actor behind tokenization or some third party) or decentralized through an authentication blockchain layer, collecting information and verifying its legitimacy without the need for third parties thanks to registration and login processes (Amakan et al., 2022). Before-reviewed winery-backed solutions include initial centralized KYC as redemption also poses some challenges in the face of tax and excise duties related to the shipment.

There are additional issues that commonly affect the broader category of crypto assets, such as securities law, anti-money laundering, sanctions and insider trading, which to a lesser extent may apply to wine-backed tokens. Securities law will have a limited impact on tokenized fine wine, as it is a collectible and does not seemingly meet the Howey test as long as they are not fractionalized (Elzweig & Trautman, 2022). Anti-money laundering is both an issue in the crypto assets sphere and art market with limited impact on tokenized wine. Transactions colliding with sanction restrictions can become a challenge, but the KYC process can mitigate this problem. Lastly, insider trading may

²⁰ Even Ethereum, originally conceived as a Proof of Work blockchain, is on the cusp of transitioning into Proof of Stake, an event that will allegedly reduce energy consumption by 99.95%. <https://ethereum.org/en/upgrades/merge/>

occur if the actors behind tokenization or third parties with access to confidential information profit out of their privileged position. Recent examples in the NFT ecosystem include an OpenSea employee that bought a token before it was advertised on the front page (Das et al., 2022). The lack of regulation and increasing adoption will likely boost the occurrence of these types of incidents.

B) *Technical restraints*

The technical backbone of the deployed tokenization application should be examined to determine the intricacies that affect functionality. As the crypto assets sphere is characterised by the presence of strong network effects (Catalini & Gans, 2020), it does not make sense for wineries to choose minor blockchain networks or design one according to their criteria for tokenizing their wines. There are basic criteria that need to be met, namely offering smart contract capabilities, different standards of token contracts, and preferably low gas fees and fast transactions. Interoperability between different blockchain networks is another limiting factor that in the long term should be ideally solved through third-party solutions. Lastly, respecting the blockchain trilemma (security, decentralization, scalability), security is the factor to prioritize, as scalability is not likely to be a problem for wine token trading.

The blockchain of choice will determine variables such as the programming language behind the smart contract, the available token standards, the cost of gas and the speed of transactions. Most current applications are developed and deployed in Ethereum, as it is the network that hosts the greatest number of decentralized applications (DApps). Programming language can be important in terms of finding a wide pool of software engineers and project developers. Solidity is both used in the Ethereum blockchain and Binance Smart Chain. Other alternatives could be Cardano with Haskell or Tezos with Michelson as programming languages for smart contract creation. Regarding token standards, current tokenized wine collections have employed ERC-721/ERC-1135 (Wang et al., 2021), both supporting the mintage of NFTs. Gas prices in Ethereum have been extremely high in moments of large market activity, but as of July 2022, they have come down to lower levels.²¹ Binance Smart Chain, Cardano and Tezos are different blockchain networks that have over time maintained lower gas prices. Regarding single transactions

²¹ Ethereum's average gas fee wandered between \$20 and \$40 between January 2021 and May 2022. As of late July 2022, average transaction gas fees are under \$1.

or whole network output of transactions per second, all the alternatives offer enough speed for trading collectibles like wine.

Interoperability is an ever-present factor in blockchain applications due to the fragmentation of the current landscape. Second-generation blockchains provide wide functionality thanks to their different capabilities, appealing to a variety of use cases. The increase in the number of unconnected blockchain networks has resulted in gaps where it is initially unfeasible to send tokens, execute smart contracts or check the validity of data from one blockchain network to another (Schulte et al., 2019). In the case of interoperability being unattainable, agents that decide to incur in wine tokenization will opt for the blockchain with the most users, software developers, applications or security guarantees. The absence of interoperability could exacerbate winner-takes-all scenarios where only a few blockchains will in the long term survival. The different approaches to take on this challenge are public connectors,²² providing interoperability between cryptocurrency systems; so-called “blockchain of blockchains” (or multi-blockchain) frameworks that offer an interoperable ecosystem, such as Polkadot or Cosmos, through external infrastructure; and hybrid connectors, directed at interoperability between public and private blockchains (Belchior et al., 2021). Future developments will bring more practical solutions in the search for universal interoperability, limiting the medium to long-term risk of wine-backed tokens being valuable in their own silo.

The blockchain trilemma is a concept that seeks to explain the trade-offs between scalability, security and decentralization. Security and decentralization are two of the core properties of blockchain, whereas scalability is the variable where solutions are being researched and developed to increase it without compromising the other two traits (Hafid et al., 2020). In the case of tokenized wine, the blockchain trilemma is not the main challenge regarding architecture as scalability is a welcomed factor but not strictly fundamental. Tokenizing actors should consider security as the primordial trait, even if the physical nature of the underlying wine and prior KYC could mitigate the negative effects of an exploit. Lastly, decentralization is the greatest in those blockchain networks where there is no single controlling entity and decision-making is at the hands of a great

²² Namely, sidechains (independent blockchains connected to the main chain via a two-way bridge such as Polygon), notary systems (such as centralized and decentralized exchanges) and hash-time locked contracts (such as Bitcoin's Lightning Network).

number of independent nodes. Reviewed current wine-token collections are based on Ethereum, which is definitely decentralized.

C) Information asymmetries

The third factor that could limit the adoption rate of tokenization as a standard for investing in fine wine is the are the dishonest actions aimed at taking advantage of the information asymmetries that can arise from tokenization. As tokens are backed by wine, critical data from the physical world has to be inserted into the blockchain. An oracle is a bridge between external environments (off-chain data) and on-chain smart contracts. The trustworthiness of the recorded external data depends on the credibility of the oracle, raising the so-called oracle problem (Caldarelli et al., 2020). If wine were to be tokenized by trustworthy actors, such as wineries, they will be considered single trusted parties and the possibility of false data being passed by the oracle becomes a possibility. Traceability systems can be implemented to enter data through sensors, but limitations apply to the own sensor characteristics. Authenticity and traceability are concepts usually perceived as innate to blockchain that could be taken advantage of by malicious actors to mint tokens not backed by wine or by faulty wine.

Wine tokens are digital representations of their physical counterparts, but there is no definite guarantee that they are indeed backed by wine. Anybody can mint a token and declare that it represents ownership of a physical wine. Investors would be wary of non-credible tokenizers, but trustworthy actors such as wineries may also incur fraudulent practices. Wine redemption should always be guaranteed, at the expense of the pertinent taxes, tariffs or shipping costs. Even if redemption is available, a certain percentage of investors may decide on keeping the wine stored under the wings of the tokenizer and fully treat it as a tradable investment deposited at a custodian. In this context, it would be possible to issue several tokens not backed by wine proportional to the token owners that do not opt for the withdrawal.

Physical provenance is another concept that can be mistaken for the traceability of token ownership. The tracking of transactions concerning a single token within the blockchain gives information about its ownership, but for data on its physical counterpart to be included a provenance system inserting data measured by sensors has to be present. In the case of such an application not being implemented, counterfeits or not correctly kept wine could easily reach the market. In the past, even auction houses that conduct

authenticity checks and filter out suspicious bottles have been involved in notable scandals such as Hardy Rodenstock's Thomas Jefferson Wine bottles (Holmberg, 2010) and wines sold by convicted fraudster Rudy Kurniawan (Fougere et al., 2020). The same applies to wine stored across time in inadequate conditions, as these bottles could reach the secondary market as tokens when most physical distribution channels would shut them down. At present, wine traceability systems are being slowly adopted, and improvements coupled with increased user interest will provide better counterfeit prevention and brand protection (Popović et al., 2021). Displaying off-chain data on the wine behind the token grants better provenance, but challenges arise about the type of sensor, placement, scanning ability and life expectancy that can hinder the trustworthiness of the entered data.

V. Conclusion

In this paper, we develop the topic of asset tokenization and the underlying implications that arise from applying it to wine investment. We identify that the potential benefits of tokens backed by wine consist in democratization thanks to more equal access to wine investment; increased liquidity driven by cheap and fast transactions through decentralized marketplaces; disintermediation in cases where producers opt to directly offer their fine wines as tokens; an increase in transparency due to the public blockchain record of events of pseudonymous token ownership; process optimization related to both the investment in fine wine and especially the financialization of wine; and digital scarcity, as token ownership could reinforce notions of exclusivity, originality and authenticity. We propose winery-based tokenization of fine wine as a concept that could optimize the positive outcomes emerging from these factors.

Our findings indicate that, in the few recent instances where wine has been tokenized, a variety of limitations can be observed. Excluding one-off token releases – Château Angélus barrel and both Penfolds barrel and two Imperial bottles – that could be considered as rare collectibles with non-existent secondary market trading activity, only Penfolds Magill Cellar 3 2018 and Mondavi x Bernardaud constitute examples of investable fine wine. Ever since December, Robert Mondavi has only sold one-third of the initial 1,966 individual bottle-token offering, and secondary trading activity of both wines has been limited ever since release. Asset price performance can be partially attributed in both cases to ETH/USD price, as the correlation between the two variables

is 0.6472 in the case of Robert Mondavi x Bernardaud and 0.5728 for Penfolds Magill Cellar 3 2018, outliers being included, raising to 0.7238 and 0.6815 if correlation is calculated excluding outliers. All analyzed trades were executed in ETH; the observed correlation between token prices and ETH prices can be explained through low liquidity (sell price quotations being listed for months) and currency risk in the form of ETH volatile price action. Concerning the rest of the potential benefits, current wine-backed token examples offer little functionality and mostly constitute initial efforts to capitalize on the NFT trend and explore the concept of tokenization.

Wine tokenization faces challenges to its adoption in the form of legal uncertainty, technical constraints and information asymmetries. The legal framework and regulations related to crypto assets are constantly evolving, as it is a fast-developing area of increasing relevance. Wine tokens currently fall outside EU and US regulations, and it would be rare for them to be considered securities in absence of fractionalization of the underlying asset. Future regulation should protect the rights of the physical asset represented by the token, and tokenizers have to consider KYC related to wine custody and redemption. Technical restraints include smart contract capability, gas prices, interoperability or security, having all of them favourable prospects as development in the blockchain sphere will bring practical solutions benefiting actors in the wine sector interested in tokenization. The third element are information asymmetries revolving around the backing of tokens and wine provenance. Malicious actors could take advantage of the transparency associated with token ownership to incur fraud either by not backing the token with any wine or by using defectively kept wine or counterfeits. Trust in the figure behind tokenization and incorporating bottle provenance solutions could offset these challenges, although still exposed to false data being passed into the blockchain by credible actors and defects of the provenance system sensors.

This paper exposes how wine tokenization is a concept whose promising potential could solve some of the limitations of fine wine investment, although recent examples of wine tokens do not offer clear benefits over how the current fine wine market functions and there are still a variety of challenges ahead. We have explained tokenization and established the drivers that justify wine tokenization. The secondary market activity of fine wine tokens has been analyzed, advising investors to list wine tokens in stablecoins to minimize the greater exchange risk associated with cryptocurrencies like ETH. The present challenges could deter sector actors from exploring tokenization, but regulation

clarifying the aspects behind physical asset tokens is on the way and there are growing efforts that will help clarify the remaining factors. This work lays out the fundamental notions behind what to expect from understanding wine property as a digitized entry, setting out an initial precedent for subsequent research on fine wine tokenization.

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