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A Comprehensive Review of NFT Marketplace

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ABSTRACT

Non-fungibletokens(NFTs)representuniquedigitalassetsverifiedthroughblockchaintechnology,enabling ownership of both virtual and physical items. Despite the rapid growth in the creation and trading of NFTs, comprehensive research on their market dynamics remains limited. This study examines the transaction network among NFT buyers and sellers, focusing on the structural characteristics of NFT trade interactions. Our analysis reveals that a small number of participants account for most NFT transactions, while most addresses engage in only a few trades. We explore the structural properties of the NFT trades network, including centrality measures, clustering coefficients, and assortativity, and track their evolution over time. Additionally, we construct a graph of NFT relationships, identifying four major communities and highlighting leading projects within each. Our findings also indicate patterns in co-purchases, revealing which NFT projects are frequently bought together. This research contributes to a deeper understanding of the NFT market's structural dynamics and participant behaviour.

Keywords: Non-fungible tokens;NFTs; Blockchain technology;Systematicreview.

INTRODUCTION

Non-fungibletokens(NFTs)representagroundbreakinginnovationintherealmofdigitalassets,definedas―cryptographic assets on a blockchain containing unique identifying information and codes that separate them from one another‖ (Peres et al. [1]). The concept of NFTs first gained significant attention with the emergence of Crypto Kitties on the Ethereum network in late 2017 [2]. However, their rapid expansion has been closely tied to the global shifts brought about by the COVID-19pandemic, whichreshaped marketdynamicsand increasedinterestindigitalassets.FollowingtheWorldHealth Organization's declaration of the pandemic, there was a notable surge in bitcoin market liquidity [3], and many investors turned to NFT marketplaces as traditional markets faced unprecedented volatility and declining interest rates [4]. Furthermore, the pandemic's lockdown measures intensified online engagement, driving the growth of NFT adoption. DespitetheirrisingpopularityacademicresearchonNFTsremainsrelativelyscarcecomparedtotheextensiveliteratureon Bitcoin andother cryptocurrencies [5]. As NFTs are still in a formative stage, the lack of comprehensive research presents both challenges and opportunities for stakeholders in this multidisciplinary field. The exploration of NFTs necessitates insights from various domains, including computer science, economics, finance, and law [6], highlighting the complexity and potential of this evolving sector. Research into NFTs is essential, especially given the lessons learned from the development of cryptocurrencies. Scholars predict that NFTs could leverage the capabilities of decentralized ledgers to a greater extent, potentially leading to transformative impacts in financial and economic contexts [7]. By introducing digital scarcity, NFTs redefine ownership and enhance the value of digital assets [8][9]. They also create new economic opportunities for content creators, allowing for more efficient market participation and reducing reliance on intermediaries [10]. However, with these advancements come significant regulatory challenges, including concerns over speculation,fraud, and market volatility [11]. This paper aims to provide a comprehensive review of the current NFT literature, serving as a resource for emerging researchers and practitioners in the field. The study addresses the following research questions (RQs):

RQ1:Whatisthecurrentstateoftheareaofstudy? RQ2:
What is the direction of NFT's evolution?
RQ3:WhatarethecommonchallengesthatNFTsmustovercome? RQ4:

How will NFTs evolve in the coming years?

The structure of this research is organized as follows: The second section outlines the research methodology for literature selectionandanalysis.Thethirdsectionreviewstheexisting NFTliterature,identifyingkeypapersanddiscussingmajor

themes and issues. The section concludes with insights into future developments in the field. Finally, the report closes with a summary of findings and implications for ongoing research in NFTs.

LITERATUREREVIEW

PlanningtheReview

This study synthesis aimed to assess the present status of NFT. This investigation was conducted with the greatest seriousness by thoroughly reviewing all current relevant literature. Utilizing organized RQs, databases, and techniques for locating and evaluating material is integral to the review approach. Certain elements of the specified reporting items for systematic reviews were selected to give a clear, quantitative, and thorough assessment of NFT. The entire plan comprises the following important steps:

I. Analysingthestateofthefieldatthemoment.
II. Understandingtheevolutiontrendsofthestudy.
III. Determiningthefield'sdifficultiesandpotentialfuturepaths.
IV. Asummaryoftheinvestigation'sresults.

ResearchStrategy

A holistic review of the literature necessitates an inclusive perspective. Before the search, a sufficient number of databases were chosen to enhance the likelihood of locating highly relevant articles. Throughout the study, Scopus sources are examined.

SearchCriteria

To ensure that the information presented here is comprehensive, relevant databases were exhaustivelyexamined. However, not all great works of literature have been included in the search criteria for a variety of reasons. To achieve this goal, a complete literature search was performed. Approximately 127 Scopus results have been examined, published before November 2022. Thirty-four were deemed significant (Figure 1).

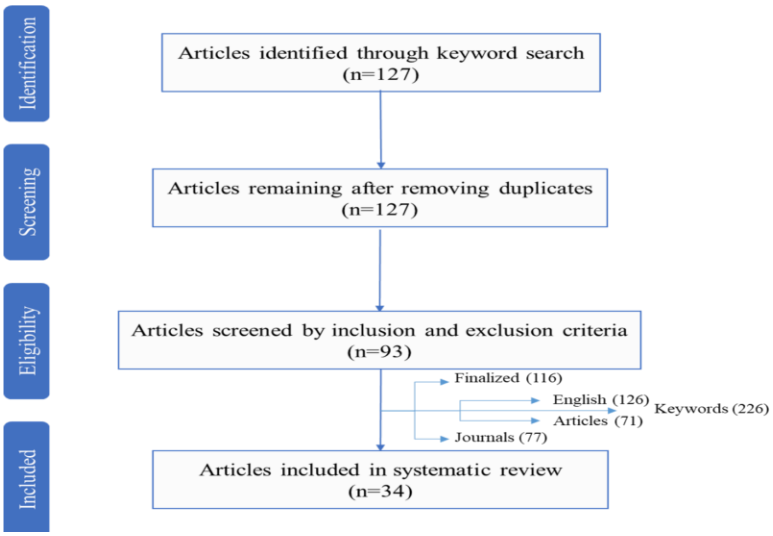

Figure1.Diagramdepictingtheselectionof studiesforasystematicreview

Studydomainandresearchtopicsaffectedthedevelopmentofthesearchstring.Bysearching—NFT‖AND—Non-fungible token‖ pertinent information was identified and collected.

(I)Inclusioncriteria(IC)

- Researchpublishedatanypointbetween2012and2022.
- The keywordsinclude—Blockchain‖,—Block-chain‖,—Non-fungible Token‖,and—NFT‖.
- Theresearchscopeisrestrictedtothejournal.

(II)Exclusioncriteria(EC)

- Theeliminationofarticlesinthepress.
- ArticlesthatarenotinEnglish.
- Exclusionofreviews,conferences,bookchapters,dissertations,monographs,andworksbasedoninterviews.

RESULTANDDISCUSSION

Table1.Severalarticlesacrossdifferentjournal

Journals	Number of Publications
IEEEAccess	5
FinanceResearchLetters	4
Mathematics	3
ScientificReports	2
Sensors	2
AppliedSciencesSwitzerland	1
AutomationInConstruction	1
Buildings	1
BusinessHorizons	1
ComputerCommunications	1
CrimeMediaCulture	1
EconomicsLetters	1
EnergyResearchandSocialScience	1
FashionStyleandPopularCulture	1
IEEETransactionsonGreenCommunicationsand Networking	1
InformationProcessingandManagement	1
InternationalJournalofEnvironmentalResearch andPublicHealth	1
InternationalJournalofInnovativeComputingInformation andControl	1
InternationalJournalofLawandInformation Technology	1
InternationalReviewofFinancialAnalysis	1
JournalofBusinessVenturingInsights	1
JournalofCulturalEconomics	1
OperationalResearch	1

The results of answering the RQs given in the preceding systematic revieware as follows. This study seems to substantially advance the use of NFTs.This section describes NFTs and their foundations, variations, development teams, platforms, and consensus procedures. The importance of employing NFTs will be discussed in further detail in the future.

SelectionResults

Intotal,93ofthe127itemsthatthissearchproduced were screened.Thissystematicreviewincludes34articles.Belowisa list of the papers that were chosen, along with explanations of the general categorization findings. The review process's limitation is that the database is mainly Scopus.

RQ1:Whatisthecurrentstateoftheareaofstudy?

Thissystematicanalysisexaminesthecollected descriptivedataonthedifferentarticlespublishedeach year,thepublishing source, and the annual average number of citations that research publications receive. The examination of NFT research paperspublishedbetween2012and2022iscompletedinthissystematicreview.Thenumberofreferencedresearcharticles is shown in (Table 1)along with the relevant journals.

The number of articles produced for each topic area from 2012 to 2022 is shown in (Figure 2.) The main subject areas are ComputerScience(14articles)andEngineering(12articles).OthersubjectsincludeEconomics,EconometricsandFinance (7articles), MaterialsScience (7articles),Mathematics(5articles),SocialSciences(5articles), Business,Management and Accounting (4 articles), Physics and Astronomy (3 articles), Biochemistry(2 articles), Genetics and Molecular Biology (2 articles), Chemistry (2 articles), Decision Sciences (2 articles), Energy (2 articles), Multidisciplinary (2 articles), Arts and Humanities (1 article), Chemical Engineering (1 article), Environmental Science (1 article), Medicine (1 article), and Psychology (1 article).

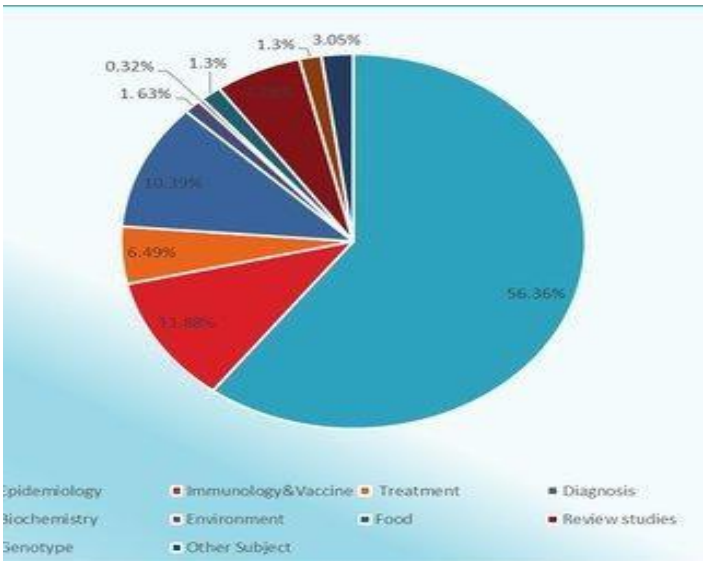

Figure2Thenumberofpaperswrittenbasedonthesubjectareabetween2012and2022.

Kevin McCoy created the first NFT in 2014 and dubbed it Quantum on the Name coin blockchain [1]. Dermody and his colleague founded Counterpartyin 2014, a peer-to-peer financial platformand an open-source, distributed internet protocol based on the bitcoin blockchain. Throughout the process, an increasing number of projects and assets were created, including a trading card game (2015) and a meme trading game (2016) [2]. With the Ethereum blockchain and what constitutes an NFT today, real NFTs migrated to Ethereum only after 2017. Between 2012 and 2022,

(Figure 3) depicts the number of articles published year. There is no accessible material from 2012 to 2019. Between 2018 and 2021, there is a gradual increase in public awareness of NFTs, followed by an adoption explosion in early 2021. In 2020, only a single paper was published. The quantity of articles has grown from 2020 to 2022. There were 5 articles published in 2021, followed by 28 articles in 2022 (almost 82% of total articles). In 2022, the number of publications has expanded substantially.

(Figure 4)shows the proportion of writers by nationality. China has the greatest number of writers. The United States, Ireland, Australia, and the United Arab Emirates, among others, followed.

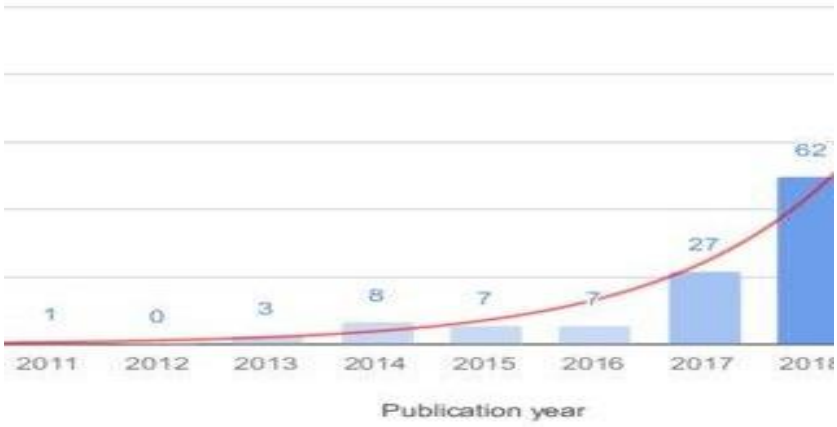

Figure3Thenumberofpublicationspublishedyearbetween2012and2022.

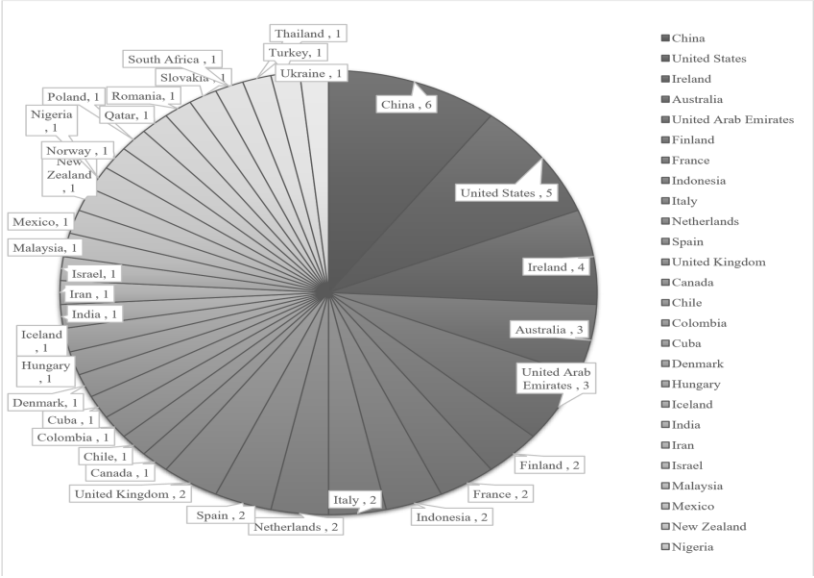

Figure4.Authordistributionbynation RQ2:

What is the direction of NFT's evolution?

Already in 2012–2013, hashes of files or other data were added to the Bitcoin blockchain to authenticate their existence or legitimacyatacertainmoment[12].Thisdevelopmentservedasthefoundationforthecreationof―ColoredCoins,‖tokens that are uniquely identified by introducing metadata to Bitcoin transactions, and ―Namecoin,‖ a separate blockchain that uses tokens to establish an alternative, decentralized top-level domain name system by deploying tokens for domain name registration [13]. Counterparty, is another attempt, offering enhanced capabilities for more generalized uses of NFTs on the Bitcoin blockchain and the first blockchain-based trading cards [14].The projects and businesses grew and diversified their activities even more in 2018 [15]. The markets and supporting infrastructure grew enormously, fueled by venture finance, cryptocurrency investments, and buzz [16]. As a consequence of this growth, music songs, physical things, academic papers, and a great deal more have been included in NFTs. In some cases, these were only experiments, in others, the founders or investors were searching for their niche, while others assert that this tokenization process would result in a new property system. As change has progressed, the art world has been lured into partnerships between established art world organizations such as Art Basel and technological firms. The proponents of cryptocurrencies promise enhanced artist

compensation,disintermediation,andbettercompliancewith impending anti-money-laundering rules as business reasons

for these collaborations [17]. The top 10 papers that were mentioned the most between 2012 and 2017 are shownin (Table2).

Table2:**Thetop10paperthatwerementionedthemostbetween2012and2017**

Title	First author	Journal	IF (2019)	Year	Citations (WoS)	WoS sort
Diagnostic criteria for mild cognitive impairment in Parkinson's disease: movement disorder society task force guidelines	Litvan, I	Movement disorders	10.338	2012	1,312	Clinical neurology
Tai Chi and postural stability in patients with Parkinson's disease	Li, FZ	New England journal of medicine	91.253	2012	429	Medicine, general and internal
Consensus statement on the classification of tremors. from the task force on tremor of the international Parkinson and movement disorder society	Bhatia, KP	Movement disorders	10.338	2018	413	Clinical neurology
How to identify tremor dominant and postural instability/gait difficulty groups with the movement disorder society unified Parkinson's disease rating scale: comparison with the unified Parkinson's disease rating scale	Stebbins, GT	Movement disorders	10.338	2013	362	Clinical neurology
Exercise-enhanced neuroplasticity targeting motor and cognitive circuitry in Parkinson's disease	Petzinger, GM	Lancet neurology	44.182	2013	340	Clinical Neurology
Accuracy of the Microsoft kinect sensor for measuring movement in people with Parkinson's disease	Galna, B	Gait and posture	2.84	2014	304	Neurosciences, Orthopedics, Sport Sciences
International Parkinson and movement disorder society evidence-based medicine review: update on treatments for the motor symptoms of Parkinson's disease	Fox, SH	Movement disorders	10.338	2018	255	Clinical neurology
A redox modulatory Mn3O4 nanozyme with multi-enzyme activity provides efficient cytoprotection to human cells in a Parkinson's disease model	Singh, N	Angewandte chemie-international edition	15.336	2017	220	Chemistry, Multidisciplinary
Opicapone as an adjunct to levodopa in patients with Parkinson's disease and end-of-dose motor fluctuations: a randomized, double-blind, controlled trial	Ferreira, JJ	Lancet neurology	44.182	2016	215	Clinical neurology
Glucocerebrosidase activity in Parkinson's disease with and without GBA mutations	Alcalay, RN	Brain	13.501	2015	198	Clinical neurology, Neurosciences

WoS, web of science; IF, impact factor.

RQ3:WhatarethecommonchallengesthatNFTsmustovercome?

The major pressing issues raised by NFTs are the uncertainties surrounding the legal rights and financial benefits provided by NFTs and the environmental effects of the underlying blockchain.The ease of creating ―digital editions‖ of art or collectibles on an open, economically liquid, value-transfer network has created new income streams for artists, museums, and businesses. In addition, some supporters contend that NFTs ―may be able to democratize art‖ [18] since they enable a wide range of individuals to share the born-digital art and are paid for doing so. In contrast to promises made by NFT initiatives, however, there is little proof that it, compared with other online monetization types, helps artists' problems in earning a livelihood [19].NFTs are publicly available and do not function to support many artists financially from a copyright viewpoint; therefore, those who can build a following (particularly among crypto natives) and previously known artists tend to fare better [20].

Anything capable of being digitized can be converted into an NFT. However, there is a growing interest in NFTs from the copyright perspective, in part because many of the works being traded as NFTs, such as works of art, are copyright-protected, and also because there is a lack of clarityregarding what exactly is acquired when purchasing an NFT. NFTsare not subject to digital rights management, unlike other well-liked material such as streaming services, and may thus be accessed by anybody and many users at once. NFT supporters view these pieces of information as the beginning of a new economic system and the release of artists and their work from the grip of the art market, while detractors and skeptics seeit as capitalism in overdrive as a consequence of the commoditization and securitization of art. Commoditization is seeing art as just another tradeable item rather than a valuable object in and of itself. Securitization is the process of converting anything into a financial instrument for use in financial speculation, which also permits fractionalizing (dividing an item into shares). NFT opponents decry widespread fraud and speculation and assert that the economic models used by NFT initiatives do not provide any non-capitalist incentives, such as a more equitable economic structure.Regarding environmental issues, the majority of NFTs now in use are proof-of-work blockchains, which are criticized for their high energy requirements for security and operation. To lessen the environmental effect, there are second-layer systems or blockchains based on proof-of-stake that are either currently available or under development. However, as with manypublic blockchains, the amount of energy needed is now a major argument against NFTs [11].The disappearance of connections(also knownas―linkrot‖)andaccusationsofmoneylaunderingand fraudarefurthertechnicalandsocio-legal difficultiesbroughtupbyNFTs.―Linkrot‖is aseriousissuesince manyNFTs merelyprovidealinkto the tokenized text. This phrase refers to the circumstance in which a hyperlink no longer directs users to their intended destination because the relevant hosting provider no longer provides access to it. A decentralized storage system such as IPFS relies on users

sharing data through their nodes or purchasing ―pinning‖ as a service [12].

RQ4:HowwillNFTsevolveinthecomingyears?
NFTs are immutable digital assets that reflect works of art, musical compositions, and other real-world artifacts that reside on a blockchain. The market for non-fiat currencies is resilient and dynamic, increasing the number of NFT transactionsand users. Future studies will further include NFT material that was omitted from this analysis but is of significant value, particularlytheoreticalpublicationsand commonknowledgefromthecryptocurrencyindustry,proposing manybroad areas for future NFT research.

NFTsasimmutabledigitalassetsrepresent physical itemssuchas songsorpaintingsona blockchain.NFT transactions and users continue to rise as a result of the market's resilience and vitality. Many broad topics for future NFT research have been proposed, including research into the excluded NFT content that is of substantial worth, such as common knowledge and theoretical articles from the bitcoin sector.

Tokenomics
Tokenomics is a system of economics based on tokenization comprising token characteristics, monetary policy, and user incentive mechanisms [13]. In tokenomics, everyone receives tokens as compensation for their participation and uses those tokens to buy goods and services. The term ―tokenomics‖ refers to the token allocation method's economic behavior in comparison to the market economy's mechanism for allocating resources. There are three major categories of tokens based on their intended use [14]. The first kind includes payment tokens, also known as coins, such as Bitcoin and Ethereum. In contrast to FTs, which are distinct and divisible, these tokens do not adhere to the NFT principle. Utility tokens are the second kind of token, and they're meant to provide users with digital access to a certain app or service. The third kind, Assettokens,hasseenahuge expansioninusethanksto the adventofNFT.Tokenomicsstudieshaveso far focused onthe development, distribution, and management of token ecosystems. All of the results that were presented from this sample were designed for tokens that may be used several times. Howell et al. [14] argue that, if conducted properly, tokenissuance has the potential to outperform conventional financial instruments in terms of safety, liquidity, and transparency. Tokens are introduced to decrease the effective carry cost of completing platform transactions, which speeds up the adoption of productive platforms, as shown by Cong et al. [15], who give one tractable dynamic equilibrium framework of token price and platform adoption. Except when the platform expects high cash flows, has big funding needs, or confronts serious agency conflicts, Gryglewicz et al. [16] show that token financing is preferable to stock financing. Future research on NFTs may continue in this paradigm by drawing parallels to FTs. Research potential is increased by focusing on the theoretical application and impact of NFTs. For example, NFTs have led to remarkable growth in the digital market and incentives for individual producers, but questions regarding how to build a more efficient marketplace remain unanswered [20]. Furthermore, NFTs are considered an integral part of the Web3.0 and metaverse [17], but there is a lack of state-of- the-art theoretical research on how to build NFT-based ecosystems.

Metaverse
Metaverses are defined byan increasing number of interactions between users. To allowresponsive engagement, the speed of the consensus mechanism must be considered. As compromise solution algorithms develop over time, it may become possible to examine metaverses in more depth. Metaverses provide more comprehensive data than internet history. Consequently, user information must be safeguarded in an especially secure way. To do this, an additional study must be conducted on user protection. Due to metaverses' decentralized control, entities such as the police or government may be required to safeguard users from harm [17]. This includes offensive material and fraud. How implementation may occur should be investigated further.

Regulationandrisk
On the one hand, fraud is a significant factor to take into account when working with cryptocurrencies, and the price of NFTs may be subject to market manipulation or other dishonest actions [20]. Therefore, further study is required in the future or existing NFT market to warn or uncover the associated hazards. On the other hand, NFT mining and trading activities can provide unsustainable profits and skew investor expectations, ultimately exacerbating the market bubble caused bythe enormous influxof fresh money. Concerns exist over the possible impact ofNFTs onother financial markets and cryptocurrencies. The NFT business is currently small enough for politicians and regulators that legislation would impede its development and potential advantages, but its growth should be continuously monitored [11]. Traditional centralized regulatory frameworks have been affected bythe cryptocurrency and NFT industry's emphasis on collaborative maintenance, self-management, and decentralization. Researchers must keep looking at and evaluating NFTs from the perspectiveofruleformation and mechanismimprovementiftheywantto constructa modelthatismutuallybeneficialand synergistic.

Videogames
The video game business has to determine whether NFTs are an improvement over traditional games. For instance, a USD 300 starter package is needed for the blockchain game Axie Infinity [18]. The high cost of certain NFT games raises the issue of whether or not the extra moneyis worth it for players, or whether or not the developers are just tryingto maximize their profits. Since the blockchain video game industry grows, it is essential to establish whether scalability is sufficient, as the scalability and speed of a blockchain depend on the chosen consensus algorithm [19]. The video game business is fraught with peril that might lead to the destruction of valuable possessions. The video game business requires easyaccess; hence, the NFT concept has to be simplified. The potential risks to buyers must be communicated [21].

Assetvaluation
Research in this area may be hectic right now, but there is room for greater output and clearer pathways to be developed. The first concern is whether or not there is a standard methodology for establishing the value of NFTs. Although it would be possible to do so with a single NFT market, others need further investigation [22]. Other factors might be investigated and added to the study [23], such as market sentiment, financial and economic policy uncertainty, pure volatility indices, and so on.The second goal isto define the link between NFTs and other cryptocurrencies, as well as the elements [24] that drive both markets, such as the Consumer Sentiment Index (CSI), the Consumer Confidence Index (CCI), economic policy uncertainty (EPU), and the Volatility Index (VIX) [25]. Since more and more investors are likely to start using NFTs, its impacts and links with a wider range of assets are likely to become an important area of study.

DISCUSSION

Reflectionsonmainresults
The NFT market is a very young phenomenon, which in turn emerged from similarly recent technological phenomena (blockchain around 2009 and smart contracts around 2015). Within this short period of time, the market has already experienced several peaks, includingthe great success of CryptoKitties (fromlate 2017) and the market boomthat beganin 2021 in the form of an extreme growth in trading volume. Our results and visual analysis indicate that the NFT market should be viewed from diverse angles (revenue, activity, users). Given that the NFT market is highly dependent on the larger cryptocurrency markets (Ante 2021a), the question naturally arises to what extent the huge NFT trading volume in early 2021 has merely been due to rising cryptocurrency prices. Accordingly, it would be worthwhile to investigate the pricing of NFTs in relation to the price of Ether or Bitcoin, and to what extent the cryptocurrency market drives the token prices in the much smaller NFT markets, which in turn drive NFT sales, volume and wallet activity.

The present study's financial focus on the NFT market is quite novel. It complements Nadini et al. (2021), who also mapthe NFT market but focus more on the interaction between NFT objects, traders and sectors, rather than on individual projects. In looking at individual NFT projects, our study is also related to Dowling (2021a), who examines the pricing of three NFT submarkets but focuses on the relationship with the cryptocurrency market (Bitcoin and Ethereum), similarly to Ante (2021a).

Our results suggest that NFT markets are driven by other NFT markets. The largest projects are currently assignable to the collectibles, metaverse, gaming, and art sectors. NFT projects with widely diverging content can nevertheless have a significant influence on each other—which initially seems counterintuitive. For example, the metaverse project Decentraland Grangercausestheart marketplace SuperRare intermsoftrading volume. However,thisis mostlikelyrelated to the fact that SuperRare joined the Decentraland marketplace so that Decentraland users can use their native digital currencyMANAwithinSuperRare(Decentraland,2020).Itcanbeasensiblestrategyfor younger NFT projectstooffer the native tokens or currencies of larger NFT projects (or cryptocurrency projects) on their platforms or to integrate their own produce or services within the larger platforms to attract additional existing users with an affinity to NFTs. This strategy is particularly valid if the partner projects differs in terms of content, i.e. it does not constitute direct competition.

The high degree of interrelation within the NFT market is also evidenced by the fact that the younger project Somnium Space Granger-causes several other projects, though this effect seems to be negative. More sales of Somnium Space NFTs (digital parcels) lead to fewer NFT sales of other projects, which suggests that NFT users are"poached".The occurrence of both negative and reinforcing relationships between the projects suggests that pairwise relationships should be consideredin more detail. A holistic assessment of the interaction within the market should only be made with caution.

Arguably, what we have seen so far in terms of the range of applications of NFTs is but the tip of the iceberg. Additional sectors that stand to benefit from this technology include financial markets (e.g, Uniswap, 2021), tourism (e.g., Regner et

al.,2019),andsports (e.g.,fan tokens).Irrespectiveof any speculativebubbles,theuniqueandsecuremapping ofdigital

rights is likely to remain in demand. A major obstacle to the wider adoption of NFTs, however, is the lack of technical and legal standards that would allow established companies to develop or use NFTs and provide legal certainty for end users. While technical standards already exist for the decentralized anchoring of NFTs on the blockchain, such as the ERC-721 NFT standard on Ethereum (Entriken et al., 2018), many other legal and technical issues of NFTs remain open. For example, inthe case ofdigital art, it iscompletelyunclear howand where the actual image must or should be stored (e.g., a centralized server or the InterPlanetary File System (IPFS)), and the legal rights to NFTs are insufficiently clarified. Can a NFT owner really enforce her rights? And does this differ by jurisdiction? A salient example of this is an incident in the context of the sale of tweet NFTs. The platform Valuables allows users to auction off tweets, as in the sale of the first-ever tweet for $2.9 million in March 2021 (Valuables, 2021). In another case, however, an author of an auctioned tweet deleted the actual tweet after the sale, losing the digital asset in its original form (Bitcoin.com, 2021).

Since NFTs represent a young phenomenon and there are large differences between projects in terms of technical and legal security, we assumeahighlevelofuncertaintyamongusers/investors. Accordingly,itisno surprisethat we haveidentified a high level of comovement in the NFT market. NFTs or NFT projects are highly unproven applications and assets whose long-term benefits are subject to much uncertainty. While the Beeple image mentioned in the introduction, which was auctioned for $69 million, is likely to offer high technical and legal certainty, the same often cannot be said of cheaper and less prominent projects or artworks. If something goes wrong in an individual case, this can rebound on the entire NFT industry, which could be an explanation for the high level of co-movement.

Limitationsandfutureresearch

A key academic and practical challenge for the NFT market is to identify to what extent the observed transactions are "genuine", as oppose to representing critical market phenomena such as wash trading, tax evasion or money laundering. In this study, we have used unique blockchain wallets as a proxy for actual users. However, due to the pseudonymous natureof the Ethereum blockchain, a single person may use any number of wallets. In the context of wash trading, a common phenomenon in the cryptocurrency market (Le Pennec et al., 2021), individual market participants could trade NFTs between their own wallets to artificially inflate liquidity and thereby raise the attractiveness of the tokens to uninformed traders. Likewise, NFTs could be sold "cheaply" and bought back at a high price in order to evade taxes or laundermoney. At this point, we do not know how prevalent these phenomena are in the NFT market. While we have consistentlydescribed and analysed the NFT market, we cannot say how much of that activity is "real".

For a more holistic overviewofthe NFT market, future studies should drawtheir data not just fromEthereumbut also from other blockchain infrastructures. A cross-blockchain view would also enable an investigation of the impact of the transaction costs and scalability of blockchains on the adoption of NFTs or NFT projects. It remains unclear, for example, whether CryptoKitties would have achieved significantly more users or trading volume in 2017 if the limited transaction processing capabilities of the Ethereum blockchain had not made trading the NFTs very expensive. NFT projects are increasingly launching on other blockchains or migrating away from Ethereum (―chain swap‖) to enjoy cheaper or faster blockchain infrastructures. This phenomenon offers an exciting basis for scientific investigation, as the projects face an interesting trade-off. While the Ethereum blockchain is deemed to have the highest number of NFT-savvy users, making it an ideal launch platform, its technical constraints severely limit subsequent project growth, which suggest the transition to another blockchain. At this point, it is by no means clear what exactly drives these decisions, what their effects are, andhow old and new users will react.

It is also important to remember that the three characteristics that we have investigated are not the only means by which NFT projects can be differentiated. For example, NFTs may simply serve as a digital proof on wallets to gain access to a system or to participate in voting. Likewise, NFTs can be linked to future events, which could (but must not) mean that no transactions are even possible or meaningful before a certain date. This implies the limitation that the projects examined in this study need not be the most "relevant" NFT projects on Ethereum. Future research could look in more detail at theactual rights conveyed by each token to enable a more accurate assessment of the extent to which those rights explain metrics such as sales or transactions, and the extent to which the "market relevance" of NFT projects can be meaningfully captured or interpreted. NFTs may include other characteristics such as revenuesharing or voting rights, which can significantly influence the frequency of transactions or the trading volume. In addition, future studies may examine the impact of project-specific cryptocurrencies on adoption and trading—for example the extent to which the pricedevelopment of the digital currency MANA is related to activity around Decentraland NFTs.

Future research may want to analyse the identified relationships between NFT projects in more detail or to examine their persistence over time. For example, one could investigate whether the SuperRare marketplace indeed benefitted from

offeringitsservicesonDecentraland.Furthermore,theimpactofthelaunchofanew(successful)NFTprojectonother

(similar) projects could be investigated. For example, our results show that the CryptoPunks project did not regain a significant market share until the NFT market tookoffin2021, suggestingthat the recent "success" ofthe project is mostly due to the growth of the overall NFT market. While our results showthat various characteristics of CryptoPunks are driven by those of younger projects, which supports this assumption, further substantiation is required.

NFTs may include other characteristics such as revenue-sharing or voting rights, which can significantly influence the frequency of transactions or the trading volume. In addition, future studies may examine the impact of project-specific cryptocurrencies on adoption and trading— for example the extent to which the price development of the digital currency MANA is related to activity around Decentraland NFTs.

CONCLUSION

This study provides a comprehensive analysis of the NFT market on the Ethereum blockchain, highlighting its evolution from2012 to 2022 and examining significant submarkets. It notes that NFT transactions peaked in late 2017, while trading volume and active wallets surged in early 2021. An analysis of 14 key projects, defined by a cumulative trading volume of at least $10 million, revealed a long-run equilibrium relationship among NFT transactions, volume (in USD), and active wallets through the use of daily time series data. Employing a Vector Error Correction Model (VECM) within a Vector Autoregression (VAR) framework, the research identified numerous Granger causalities, indicating both long-run and significant short-run relationships between projects. The results show that the NFT submarkets are interdependent, with newer projects revitalizing older, inactive ones and vice versa. Despite the market's relative immaturity, it is developing rapidly, demonstrating dynamic interactions that suggest a need for further exploration and understanding of NFTs as a distinct asset class with unique regulatory and economic implications.

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