The illusion of the metaverse and meta-economy

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Abstract

This paper provides (i) a review of the existing literature on the metaverse and (ii) an empirical assessment of the current state of the Web3 meta-economy, with the focus on economic governance and metaverse commerce. We have analysed the entire Web3 metaverse niche, i.e. both the 196 available metaverse fungible tokens and all the non-fungible token (NFT) transactions belonging to the metaverse marketplace. Our results showed that economic governance is based on metaverse tokens that cannot be defined as reliable virtual currencies due to their explosive behaviour, negative performance, and higher volatility compared to traditional alternatives. Paradoxically, fiat currencies and stablecoins could be more appropriate candidates for the payment infrastructure. Moreover, we also observed that NFT prices are affected by the cryptocurrency market, which highlights the risk of metaverse commerce. For future research, developers and scholars must assess the different alternatives and infrastructures that can make the metaverse a persistent reality with a proper virtual economy. However, at present, it seems that the hype has run far ahead of reality.

Citation: Vidal-Tomás, D. (2023). The illusion of the metaverse and meta-economy. International Review of Financial Analysis. Forthcoming.

JEL codes: G10 · G40

Keywords: Metaverse · Metaverse economy · Meta-economy · Digital economy · Non-fungible token · Cryptocurrency

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1. Introduction

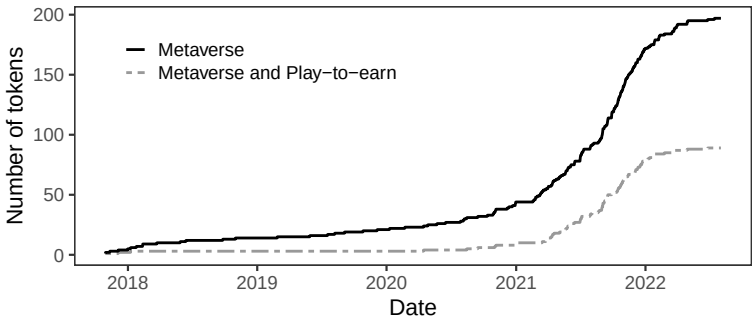
"Today we are seen as a social media company, but in our DNA we are a company that builds technology to connect people, and the metaverse is the next frontier just like social networking was when we got started." Meta CEO, Mark Zuckerberg

In October 2021, Facebook announced that it had rebranded its company name as Meta (Isaac, 2021). This change showed the company's growing ambitions beyond social media and its rising expectations on the development of the metaverse (Olivan, 2022). The emerging concept of the metaverse can be defined as a universal, persistent and immersive virtual world in three dimensions, accessible through virtual and augmented reality devices, in which users, using their own avatars, can be involved in diverse activities. Interestingly, Meta is not the only company investing in this new concept, given that (i) other giant tech companies are developing their own concept of metaverse (e.g. Microsoft and Nvidia) and (ii) hundreds of multinational firms and institutions are partners of the main Web3 metaverses, The Sandbox and Decentraland. However, the proper development of the metaverse strongly depends on the future of the technologies and ecosystem factors that drive the transition from the current Internet to the metaverse. As reported by Lee et al. (2021), there are eight possible enabling technologies (extended reality, user interactivity, artificial intelligence, blockchain, computer vision, IOT and robotics, edge and cloud computing, and future mobile networks) and six ecosystem aspects (avatar, content creation, virtual economy, social acceptability, security and privacy, and trust and accountability) that must be enhanced to allow human users to live and play within a persistent, shared, and immersive digital space.

At present, the concept of the metaverse has been related to the crypto-metaverse and Web3, since it incorporates the blockchain into its underlying technology and economy, with the subsequent benefits [e.g. decentralisation of the economy or efficient data storage, see Sec.(2.3)]. Consequently, cryptocurrencies, Web3 tokens, and crypto wallets are possible candidates for the cornerstone of the payment infrastructure. Due to this fact, in this study, we focused on the virtual economy that is built in the metaverses using Web3 infrastructures, i.e. Web3 meta-economy or metanomics. Following the research agenda provided by Lee et al. (2021), we identified in the virtual economy two main research areas that are relevant for the metaverse industry's market structure: (i) economic governance and (ii) metaverse commerce. Economic governance is focused on the creation of an in-game economic system, whose underlying challenge is to establish a reliable virtual currency from an economic perspective. The token SAND in The Sandbox, and MANA in Decentraland are the main representatives of the Web3 metaverse niche, since they represent approximately 30% of the market capitalisation in a growing crypto sector that already includes 196 metaverse tokens and 88 metaverse and play-to-earn projects [see Fig. (1)]. However, to work as a currency, any cryptocurrency used in the metaverse must be characterised by three key properties, namely, unit of account, medium of exchange, and store of value (Davidson, 1972; Yermack, 2015; Baur and Dimpfl, 2021).[1] Unfortunately, the extreme volatility generally observed in the cryptocurrency market (see Corbet et al., 2019) could reduce the ability of metaverse tokens to function as unit of account and medium of exchange, since sellers and buyers would need to recalculate prices very frequently, which would derive into a costly and confusing procedure (Walras,

[1] The definition of these three attributes is provided in Sec.(9.1).

Figure. 1: Number of tokens over time: a) metaverse, b) metaverse & play-to-earn.



2013; Yermack, 2015). Moreover, the extreme market volatility could also affect the long-run performance of any currency, undermining its ability as store of value (Baur and Dimpfl, 2021).

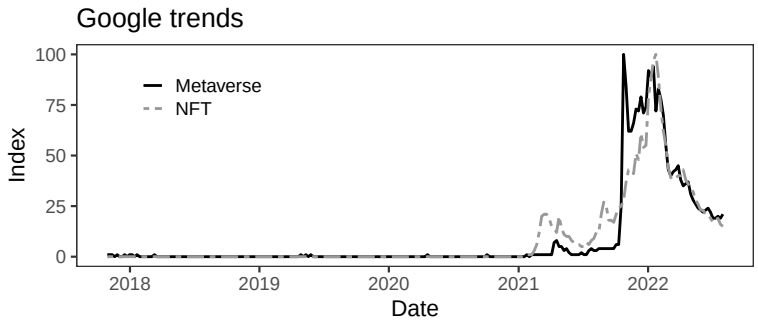
On the other hand, focusing on metaverse commerce, non-fungible tokens (NFTs) represent the main pillar of the metaverse trading system. Unlike other "fungible" assets, such Bitcoin, Ethereum, MANA, or SAND tokens, NFTs are defined as pure blockchain-enabled cryptographic assets that cannot be exchanged like-for-like (e.g. in-game items, land parcels, or any collectible). Consequently, NFTs are unique and "non-fungible" (Wang et al., 2021; Vidal-Tomás, 2022a). This intrinsic feature allows NFTs to demonstrate the authenticity and ownership of different items in distinct fields, which explains their fast expansion into the metaverse. However, similar to cryptocurrencies, NFTs are not characterised by a fundamental value, since they are only units of data (Chalmers et al., 2022). This shows the complexity of pricing these digital assets, although scholars have tried to shed some light on this problem. Indeed, some academics showed that the NFTs' value could be related to different features, such as (i) their scarcity, which will be associated with the owner' social status (Momtaz, 2022), or (ii) their address in the metaverse, as higher prices have been observed for Decentraland parcels in close proximity to the virtual city centre, plazas, main streets and business districts (Goldberg et al., 2021).

Within this framework, our paper provides (i) a review of the existing literature on the latest metaverse development, and (ii) an empirical assessment of the current state of the meta-economy in the Web3 by considering its economic governance and metaverse commerce. To do so, our analysis considered three complementary approaches. First, we briefly discussed the different aspects related to the development of the metaverse, from an economic perspective, by synthesising its history and underlining the key insights generated by the existing literature. Second, we assessed economic governance by analysing the emergence of bubbles and the performance of metaverse tokens. The absence of explosive dynamics will support the use of these tokens as medium of exchange and unit of account, and a positive (or non-negative) performance will underline store of value properties. Otherwise, virtual currencies could not hold the main properties of a currency. Therefore, our first hypothesis is that **(H1)** the meta-economy includes metaverse tokens that work as currencies from the economic perspective, since the absence of explosive behaviour and positive (non-negative) performance support their function as unit of account, medium of exchange and store of value.[2] For robustness purposes, we also compared the volatility of Web3 metaverse tokens to (i) the main fiat currencies (GBP, EUR, JPY) and (ii) a relevant virtual currency

[2]The alternative hypotheses used in this paper are included in the Appendix, Sec. (9.2).

in the Web2 (WoW token). With this approach, we contributed to a nascent literature focused on fungible tokens related to NFTs and the metaverse (see Bao and Roubaud (2022) and Baals et al. (2022) for reviews on NFTs). In particular, Maouchi et al. (2021) detected the bubble phenomenon in the summer of 2020, analysing three tokens connected with NFT activity, and Vidal-Tomás (2022a) observed some isolated volatile periods in the Metaverse index[3], which represents the main entertainment projects. Compared to the existing literature, which mainly analysed bubble dynamics on very few and heterogeneous tokens related to NFT, (i) this study is strictly focused on the metaverse financial market; (ii) we analysed the performance and bubble dynamics of the entire market, which includes 196 tokens, (iii) this is the first study analysing the role of the existing Web3 metaverse tokens as currencies from the economic perspective, (iv) we compared the volatility of metaverse tokens in the Web3 to fiat currencies and a relevant token in the Web2 (WoW token), and (v) our sample period covered from October 28, 2017, to August 1, 2022, which, based on Google searches, includes the rise and fall of the metaverse, as illustrated in Fig. (2).

Figure. 2: Worldwide Google searches for "metaverse" and "NFT". The maximum popularity during the analysed period is indicated by an index equal to 100.



Our third approach was focused on the analysis of the connectedness and causality between economic governance (i.e. financial sphere – fungible token prices/returns) and metaverse commerce (i.e. real sphere – NFT features). In this regard, it is relevant to understand the agent's consumption behaviour in the metaverse from a holistic perspective that includes the financial and real sphere. The financial sphere covers the financial activity related to the exchange of cryptocurrencies and fiat currencies in the financial market, while the real sphere considers the real and underlying economic activity that involves sales in the corresponding metaverse marketplace, such as parcels or items. A sustainable meta-economy should be characterised by a financial sphere (economic governance) that is driven by the real sphere (metaverse commerce). In other words, the value of the fungible tokens should evolve according to the underlying activity of the metaverse based on NFT features in the same way that (i) stock prices evolve according to company revenues in the traditional stock market or (ii) fiat currencies evolve according to the underlying economic activity of the country [e.g. Gross Domestic Product (GDP) or debt-to-GDP ratio]. In the same line, from the user perspective, the real sphere should be more relevant than the financial sphere, i.e. users should be attracted by a real and genuine interest in the underlying activity of the

[3]The Metaverse Index, used by Vidal-Tomás (2022a), is designed to capture the trend of entertainment, sports and business shifting to take place in virtual environments. Consequently, regardless of its name, it includes other projects that are not strictly connected with the metaverse concept used in this paper. For instance, the project Audius.

metaverse.[4] Hence, in this context, our second hypothesis is that **(H2)** the agent's consumption behaviour is based on the real sphere of the metaverse, thus, the economic governance (financial sphere - fungible token prices/returns) is driven by the metaverse commerce (real sphere – NFT features). Considering this approach, we contributed to the literature by shedding more light on the drivers of NFTs, and their connectedness with the cryptocurrency market. For instance, Dowling (2021a) analysed the pricing of parcels of virtual real estate in Decentraland and showed that the price series of these NFTs are characterised by inefficiency and a rise in value. In a follow-up study, Dowling (2021b) demonstrated the existence of limited volatility transmission effects between NFT pricing (Decentraland, Cryptopunks, and Axie Infinity) and cryptocurrencies (Bitcoin and Ethereum). Aharon and Demir (2021) observed that NFTs are mainly independent of shocks from other asset classes. Compared to these recent papers, (i) we analysed all the possible features related to the entire NFT marketplace (namely, total, primary & secondary sales, total, primary & secondary sales in USD, active wallets and average NFT price), as shown in Section (3.2), while most of the existing studies were only focused on the average NFT price (see Dowling, 2021a,b, Aharon and Demir, 2021 and Bao and Roubaud, 2022); and (ii) we exclusively considered those connections that exist in the meta-ecosystem, that is, metaverse fungible tokens and metaverse non-fungible tokens. Finally, in addition to analysing the entire metaverse marketplace, we also considered two case studies focused on the main metaverse projects, Decentraland (MANA) and The Sandbox (SAND), which allowed us to obtain a better understanding of Web3 metaverses. Hence, considering **H1** and **H2** for these *two* particular cases, our third and fourth hypotheses are that (**H3/H4**) Decentraland/The Sandbox includes metaverse tokens (namely, MANA/SAND) that work as currencies from the economic perspective, since the absence of explosive behaviour and positive (non-negative) performance support their function as unit of account, medium of exchange and store of value; and our fifth and sixth hypotheses are that (**H5/H6**) the agent's consumption behaviour in Decentraland/The Sandbox is based on the real sphere of the metaverse, thus, the economic governance (financial sphere - MANA/SAND prices) is driven by the metaverse commerce (real sphere – NFT features in the Decentraland/The Sandbox marketplace).

With this study, we provided the first integral analysis on the virtual economy of the metaverse. We included both a review and an empirical analysis, extending the research agendas provided by Lee et al. (2021) and Momtaz (2022). Our results underscored the existence of two obstacles for the proper progress of the Web3 meta-economy. First, metaverse tokens cannot be used as currencies, due to an almost continuous explosive dynamics and a negative performance. Second, NFT prices depends on the euphoria and fear of financial markets since 2021. Nevertheless, as a positive note, the agent's consumption behaviour is mainly based on the real sphere of the metaverse, given that sales, sales in USD and active wallets are generally not affected by the financial market. In summary, we rejected **H1**, **H3** and **H4**; we could not reject **H2** and **H6**, and we could not reach a clear conclusion about **H5**, since the dominance of the real and financial sphere changed over time in Decentraland. Given this outcome, we observed that there is still a long way to go. In the future, developers and scholars must analyse the appropriate platforms and infrastructures to create a proper virtual economy. Otherwise, the metaverse will be only defined as a speculative digital world.

[4]The inverse situation would underline a scenario in which the agent's consumption behaviour is only driven by the speculation of cryptocurrency markets, i.e. users are only attracted to the metaverse due to the raising speculation in the financial cryptocurrency market, and they do not have any real interest in the underlying activity of the metaverse.

2. A review of the metaverse and meta-economy

The concept of the "metaverse" originates from the science fiction novel, Snow Crash, written by Stephenson in 1992. The term is a combination of the Greek word "meta" (meaning beyond-trascending) and the stem "verse" from "universe", denoting the next-generation Internet where the characters, as avatars, interacted with each other in a virtual world in 3D. We have witnessed 30 years' development behind the evolution of this term. However, there is no consensus on its conceptualization and researchers define the metaverse through vastly different ideas, such as lifelogging (Bruun and Stentoft, 2019), virtual socialisation (Prosegur Research, 2022), embodied internet/spatial Internet (Chayka, 2021) or an omniverse (virtual collaboration and simulation platform) (Cheng et al., 2022). Indeed, even though some authors connect the metaverse with Web3 infrastructures, such as blockchain, decentralised autonomous organisations (DAO), cryptocurrencies and NFTs (Lee et al., 2021; Moy and Gadgil, 2022), it is not clear whether the metaverse will be built in the Web3 or the traditional Web2 (Moy and Gadgil, 2022). At present, the market capitalization of Web2 firms working on metaverse technologies is $14.8 trillion (Dixon, 2021), while Web3 companies are only found in a nascent stage. In a similar line, another area of uncertainty is how we will interface with this virtual world. In theory, virtual reality (VR) and haptic and biometric technology should be the cornerstone of any metaverse. The 2018 American science fiction action film, Ready Player One, is the best example. This film describes a virtual world named "OASIS" in which everyone could connect to the virtual world through the usage of VR headset and wired gloves. Given the relevance of this technology, there are many giant firms that are acquiring VR companies. For instance, Meta purchased VR device manufacturer Oculus for a total of approximately $2 billion to develop VR technologies (Meta, 2014). However, the industry has also presented different alternatives. For instance, Linden Lab considers that webcams could be used to simulate more authentic user movements (Eng, 2022) than VR headsets and avatars. Alternatively, a third option relies on the use of new applications of AR. Mobile games like Pokemon Go, Harry Potter, Jurassic Park, and Batman already included these features where the user interact with the physical world without an immersive experience. In other words, "rather than fully immersing the user in computer-generated visuals, AR overlays digital imagery on the user's view of the actual world" (Marr, 2022). As the reader can observe, there is more uncertainty than reality in the metaverse. There is no consensus about its definition or its main components. Therefore, at present, the metaverse is an ample futuristic idea integrating different technologies to connect the physical and virtual world.

2.1. Lights: Economic and social benefits

In recent years, the metaverse has attracted enormous attention from around the world. Indeed, we are at an inflection point, where it seems that not a day goes by without a company or celebrity announcing that they are building a presence in a virtual universe. Warner Music group aims to create a new arena for musical entertainment in the virtual world of The Sandbox (Mason, 2022). HSBC bought a plot of digital land in this metaverse to engage and connect with sports, esports, and gaming users (White, 2022). The Australian Open (AO) partnered with Decentraland to offer the first major sporting event hosted in the metaverse (Shimron, 2022). Accenture developed its own metaverse, creating exact replicas of offices to welcome new employees (Leonhardt, 2022). Microsoft introduced "Microsoft Mesh" (Muchmore, 2022), which is defined as a collaboration and communications platform developed to unify holographic virtual collaboration across multiple devices,

such as VR headsets, AR (Microsoft HoloLens), laptops or smartphones. Nvidia designed the "Nvidia Omniverse" making it possible for designers, artists and reviewers to work together in real time across software applications in a shared virtual world from anywhere (Kindig, 2022). Meta introduced "Horizon worlds", defined as a new social VR world for Oculus (Meta) Quest (Meta, 2019). This increasing interest in the metaverse seems to be supported by multinational professional services companies, such as Accenture, JP Morgan, PricewaterhouseCoopers and Bloomberg. More specifically, Accenture stated that, due to the emergence of the metaverse, "over the next decade we will witness a complete transformation of nearly every environment that enterprises currently do business across" (Byrnes et al., 2022). JP Morgan indicated that "the metaverse will likely infiltrate every sector in some way in the coming years, with the market opportunity estimated at over $1 trillion in yearly revenues" (Moy and Gadgil, 2022). In the same vein, Bloomberg underlined that the market opportunity will reach approximately 800 billion dollars in 2024 and 2.5 trillion dollars in 2030 (Kanterman and Naidu, 2022), and PricewaterhouseCoopers estimated that VR and AR have the potential to boost GDP globally by 2030 by up to $1.5 trillion (Dalton and Gillham, 2022).

To explain this expected growth, the scientific community has underlined some economic and social reasons. On the one hand, the metaverse will expand access to the marketplace for customers from any part of the world, including emerging and frontier economies, and it could also eliminate vertical agency costs through DAOs (Lee et al., 2021; Bellavitis et al., 2022). Thus, virtual events could have the potential to be more profitable than physical events due to the mass audience's availability and lower costs. In 2020, a major concert held in Fortnite was seen by 45 million people and grossed around $20 million, including sales of merchandise (Brown, 2020). Governments have also considered the growth of the metaverse and virtual reality as vectors of technological development, with its consequent creation of jobs. Proof of this, the Spanish government, through the Digital Spain 2026 strategy, will allocate up to 3.8 million euros to SMEs and freelancers working on experimental development projects and process innovation in the field of technologies associated with Web3 and the metaverse (El Economista, 2022). In the same line, Byrnes et al. (2022) stated that companies looking to create metaverse experiences will require 3D artists, game designers, and experts on the platforms on which they plan to build. On the other hand, the metaverse could also promote social inclusion, due to the emergence of AR/VR technologies to create virtual identities that are not restricted by any physical disability (Momtaz, 2022), and decrease social biases, since anybody could create an avatar that is not characterised by a specific gender, race, or sexual orientation (Momtaz, 2021a). Considering the metaverse's potential for educational innovation, Pellas et al. (2021) stated that simulations and gameful experiences in VR provide opportunities for learners to apply theoretical knowledge and practice complex procedural, whose mistakes could be dangerous in the physical world. Duan et al. (2021) implemented blockchain-driven metaverse prototype of a university campus to enrich the campus life of university students and university faculties. Finally, according to Mystakidis (2022), online learning in the metaverse will be able to break the frontier of social connection and informal learning, i.e. physical presence in a classroom will cease to be a privileged educational experience.

2.2. Shadows: New names & old tales

As can be observed in the previous subsection, the growth of the metaverse could offer real value to the future society from the economic and social perspective. However, we should also consider that, in December 2021, Koduri, senior vice

president of Intel stated that "truly persistent and immersive computing, at scale and accessible by billions of humans in real time, will require even more: a 1,000-times increase in computational efficiency from today's state of the art... Beyond the hardware improvements, we also need new algorithms and software architectures as well to reach our goal." In other words, metaverse is a work in progress, and according to Meta, it will take 10 to 15 years (Vallance, 2021). Consequently, a fully immersive metaverse doesn't quite exist yet. But the hype is present everywhere.

Given this obscure timeline and uncertain future, some critics state that the metaverse is simply "the feel-good place of the exciting future" created by tech companies without enough arguments to support its use (Kim, 2021). According to Jones (2022), "the metaverse has potential to transform the way we work, socialize, party and even do business - but looking at the infrastructure that exists right now, some would accuse this industry of running before it can even walk". Indeed, the hype observed in social media and tech companies feels like a "meta déjà vu".

In June 2003, the firm Linden Lab created the first social metaverse: Second life. Second life is a multi player online virtual world that allows people to create an avatar and interact with other users. They can participate in different kinds of activities, such as exploring the world, socializing, working, participating in both individual and group activities, building, creating, shopping, and trading virtual property and services with one another. Indeed, one of its relevant features is that it has its own virtual currency, the Linden Dollar (L$), which is exchangeable with real world currency. Moreover, Linden Lab grants its players intellectual property rights in everything they create, which promotes its virtual economy, giving rise to meta-millionaires. Anshe Chung, a real-estate tycoon, became the first virtual millionaire by buying, developing, and then renting or reselling "virtual-land" in 2006 (Parloff, 2005). Hence, news underlining that digital lands in the Decentraland metaverse and Axie Infinity pet-training game were sold for $2.4 million (Howcroft, 2021) and $2.5 million (Reback, 2021), are, indeed, not new. Metaverse real state investors were already present in Second life, as they are in the current metaverses.

The growth in popularity of Second Life also attracted many multinational firms, such as Sony, Nissan, Amazon, Toyota, Adidas, American Apparel, Disney and IBM (Ludlow and Wallace, 2007). Nissan opened its Second Life dealership to provide copies of its Sentra to residents free of charge (Valdes-Dapena, 2006). Amazon, Disney, and American Apparel also set up shop in Second Life (Stokel-Walker, 2013). Even Reuters opened virtual news bureau in this virtual world, almost 20 years ago, to "report and write financial and cultural stories within and about Second Life as part of the London-based company's strategy to reach new audiences with the latest digital technologies" (Reuters, 2006). Therefore, we should not be surprised when companies like Ubisoft, Warner Music, JP Morgan, Atari or Gucci are moving into The Sandbox metaverse (Moy and Gadgil, 2022), since this tendency already existed in the past.

All the current social metaverses are advertised as 3D worlds where users can work, socialize, do business and participate in different 3D experiences. Second life was created with the same aim 20 years ago. Interestingly, the community already stressed the similarities between Second life and the current projects related to the metaverse. However, Meta underlined that its concept (very similar to the rest of competitors) does not rely on a virtual world, but a new three-dimensional space to be used and accessed in various ways: "Augmented reality glasses to stay present in the physical world, virtual reality to be fully immersed, and phones and computers to jump in from existing platforms" (Vallance, 2021). In other words, one of the key differential factors will be the immersive reality through VR/AR technologies.

Unfortunately, the efficient use of AR and VR in the metaverse is more idealistic than realistic, given (i) the lack of high-quality graphics (Wood, 2021), and (ii) the high costs of VR headsets ranging from $400 to $3500 as of 2022 (Baker, 2022). Proof of this, since August 2022, Meta increased the price of Meta Quest 2 VR headsets by $100 (from $299.99 to $399.99) to "continue to invest for the long term and keep driving the VR industry forward with best-in-class hardware, action-packed games, and cutting-edge research on the path to truly next-gen devices" (Oculus, 2022). Moreover, the drawbacks connected with VR technologies are not only related to economic issues. Biener et al. (2022) quantified the effects of exchanging a desktop-based work environment with a VR-based environment for a week. Interestingly, they observed that self-rated task load was significantly higher in VR (approximately 35%)[5], as was frustration (42%), negative affect (11%), anxiety (19%) and eye strain (48%). Their results also showed a decrease in productivity (16%) and well-being (20%), and some employees even dropped out of the study due to feeling extreme nausea, anxiety, and severe migraines, as well as discomfort with the VR headset. This uncomfortable experience has also been reported by journalists who used this new technology (Stern, 2022). These experiences are in line with the scepticism shown by Social Life's founder, Rosedale, who stated that "most of us who have a comfortable existence in our real bodies, in the real world, are going to still tend to prefer that" (Eng, 2022).

Last but not least, it is also relevant to state that policymakers have connected the metaverse with some concerns. In particular, the Council of the European Union (CEU, Analysis and Research Team, 2022) underlined the existence of some issues in the following fields: (i) protection of personal data and privacy, (ii) safety/security and jurisdiction/territoriality, (iii) governance model, (iv) social model, work and health, (v) consumer protection, intellectual property, litigation and taxation, (vi) climate & environment, and (vii) competition for standard settings. In this line, other companies (e.g. Prosegur Research, 2022) also highlighted the following problems: (i) violent behaviour, (ii) recruitment and radicalization, (iii) extortion, (iv) exposure of minors, (v) identity fraud and (vi) social polarization.

2.3. Meta-economy: Web3 vs Web2

Nowadays, the metaverse has been strictly connected with the development of Web3, mainly, because of two main reasons. First, the expectations for the metaverse are that it will connect everyone and everything around the world, consequently, vast amounts of data will be needed to store digitised assets, including digital twins for physical entities and systems, avatars, maps, etc. According to Xu et al. (2018) uploading all the data to centralised cloud servers would be unlikely due to the limited network resources. Blockchain-based data storage systems could handle such amount of data since users could create data blocks and validate and record transactions cooperatively (Li et al., 2018; Zyskind et al., 2015). Second, Duan et al. (2021) stated that digital economy is still controlled by centralized operators (e.g., large companies), which means that all the digital assets in the metaverse actually belong to the operators, rather than the users. According to these authors "to guarantee decentralisation and fairness, the blockchain must be introduced to support sustainable ecosystem operation in the metaverse". Blockchain systems that introduce smart contracts could, indeed, give rise to decentralised social ecosystems (Cai et al., 2018). NFTs could be used to guarantee the ownership of

[5]Researchers underlined that workloads in the virtual and physical work-weeks were similar.

each digital assets providing an efficient method for the value interconnection and transmission between the virtual and real world (Qin et al., 2021). Decentralised finance, fungible tokens, and decentralised exchanges could provide users with liquidity for their tokens (e.g. Uniswap) (Angeris et al., 2021). Moreover, for the metacities and metaenterprises existing in the virtual world, the organizational structure would be no longer the centralized hierarchical structure applied in real companies and cities, since they could be built with the form of DAOs (Wei, 2018). These components are connected together to create the new concept of virtual economy in the metaverse based on Web3 infrastructures, i.e. the Web3 meta-economy or metanomics. However, we should consider that the concept of meta-economy/metanomics is not new, indeed, meta-economy existed before the blockchain. The term metanomics was firstly introduced by Rob Bloomfield (Cornell Chronicle, 2007), and simply defined as "the economics of the metaverse", in which "there's a technical side, a legal side and a business side, as well as a game side". Bloomfield hosted a course on the economics of Second life where different economic features were analysed using Second life as an experimental field.

2.3.1. Meta-commerce

The traditional meta-economy, or Web2 metanomics, was present in Second life (2003), and also in all the massively multiplayer online role-playing games (MMORPGs) that were released before, during, and after Second life, such as, Everquest (1999), EVE Online (2003) and World of Warcraft (WoW) (2004). Compared to Second life, which is a "social" metaverse where players do not have a specific objective, these gaming virtual worlds are defined as "gaming" metaverses. In any gaming metaverse, the player adopts the role of a character (e.g. in a fantasy world or science-fiction world) and takes control over many of that character's actions. In nearly all these metaverses, the main goal is to develop the player's character considering the "standard" cycle: (i) performing tasks, (ii) earning virtual in-game currency or items as rewards, (iii) acquiring better equipment and level-up. This cycle also creates the virtual economy and meta-commerce given that players buy and sell items and equipment in the market. However, this process could become tedious. To circumvent it, some players began buying in-game currency, equipment, and high-level avatars from other players over different third-party platforms, such as eBay. As a consequence, the first secondary (black) markets in the real world were created. Examples could be easily found in 2001 (Patrizio, 2001): character plus extra equipment for $2,600, a suit of armor sold for $1,000, shields for $500 and accounts with equipment estimated in $26,500 (see also Parloff, 2005). Overnight, the virtual economy in "Norrath", the virtual world of Everquest, became real. According to Castronova (2001), the nominal hourly wage was about $3.42 per hour, with a GNP per capita equal to $2,266; somewhere between that of Russia and Bulgaria. A unit of Norrath's currency was traded on at $0.0107, higher than the Yen. Workers from Mexico, Indonesia, China, or Romania, were hired to play and obtain items and equipment (Parloff, 2005; Ludlow and Wallace, 2007). This kind of commerce and economy also existed in other social and gaming metaverses, like The Sims Online, Second life, Ultima Online, Guild Wars, EVE Online, WoW, Anarchy Online and Diablo II among others. It was clear that there was real money to be made in virtual worlds. However, the issue of real-money trade (or RMT, i.e., the use of real-world money to purchase in-game goods) was a problem in traditional metaverses, since (i) the trade-off between effort and reward was broken, (ii) it increased speculation with in-game items, and (ii), for most of the cases, the intellectual property right of the items belonged to the company, i.e. users were not legally allowed to buy/sell in-game items. Most firms demanded that eBay

took down auctions for all the in-game items, but other companies and websites took its place, such as "MySuperSales", "PlayerAuctions", and specially, "IGE", whose main revenue came from buying/selling WoW gold (Patrizio, 2001; Ludlow and Wallace, 2007).[6]

Back to the future. Is it possible to find commonalities between WoW, Everquest or Second life (Web2), in the 00s, and Decentraland, The Sandbox or Axie Infinity (Web3), in 2022? The answer is yes. Following Bloomfield's idea of the metaverse, users use the game part of the metaverse to speculate in the business part of the metaverse. In other words, the economy of both metaverses was characterised by speculation.[7] Axie infinity is a gaming metaverse in which players collect digital pets (NFTs) known as Axies in order to battle, breed, collect, raise, and build kingdoms. Shelly (see Nonfungible, 2022) is a digital pet that was sold for $177 in 2019. However, on 11 September 2022, it has been re-sold for $19,431.39. Readers can find other examples in platforms such as OpenSea, Rarible or Minteable among others. Moreover, given the increase in price in NFTs and cryptocurrencies, workers from different developing countries treated this kind of metaverse as their main source of income (Nunley, 2021). As can be observed, with a gap of 20 years, the economic context is quite similar: (i) gaming/social metaverses to speculate (EverQuest/Second Life - Axie infinity/Decentraland), (ii) platforms to buy and sell items (eBay - OpenSea), (iii) workers using virtual worlds to earn their main (or extra) salary.

2.3.2. Economic governance

Any virtual economy requires a virtual currency to trade virtual items. Following the virtual currency schemes proposed by the European Central Bank (2012), it is possible to classify metaverses in three categories: (i) closed virtual schemes, (ii) virtual currency schemes with unidirectional flow, and (iii) virtual currency schemes with bidirectional flow. The first one is characterised by the absence of connections with the real economy, given that the virtual currency can be only used within the virtual community and it cannot be traded outside its corresponding virtual world. Virtual currency schemes with unidirectional flow are partially connected with the real world, since the virtual currency can be purchased using fiat currency at a specific exchange rate, but users cannot exchange back virtual currencies to the original currency. Web2 metaverses like WoW and EVE Online are included in this group, since users can buy "WoW tokens - Gold" and "ISK (Inter-Stellar Kredit)", respectively. Finally, virtual currency schemes with bidirectional flow are completely connected with the real economy, given that users can buy and sell virtual money according to the exchange rates with their fiat currencies. Second life is included in this group, due to the existence of the Linder dollar and the exchange LindeX. Additionally to this categorisation, there is a significant difference between the aforementioned metaverses. In the case of metaverses like Eve Online and WoW, the value of the virtual currency is determined dynamically based on supply and demand, i.e. players' activity affect the value of the currency. For instance, EVE Online provides a player-driven complex economy as all items need to be produced from raw materials and traded by players with minimal intervention of the game developers (Belaza et al., 2020), which has given rise to several research studies about its economy (e.g. Hoefman et al.,

[6] Interestingly, Second life did not have this problem since they granted residents ownership of the intellectual property rights in their creations.

[7] In this regard, we could highlight a difference regarding the legal side of the metaverse. In particular, speculating with NFTs in the Web3 is legal, while speculating with in-game items in the Web2, through third-party platforms, is illegal, in most of the cases. At any rate, speculation is a common factor between Web2 metaverses, in the 00s, and Web3 metaverses, in 2022. We underlined the differences regarding the technical side in Sec. (7.2), where we also compared the current state of both types of metaverses in 2022.

2018). However, in Second Life, Linden Lab acts as the issuing bank in order to guarantee that the exchange rate is stable, i.e. they will keep volatility low by injecting new Linden Dollars as demand increases.

The scheme used by some Web2 metaverses like WoW and EVE online partially excludes financial speculation from the system, since only players interested in the game will exchange fiat currency for virtual currency, without the option of exchanging back virtual currency to the original currency. In the case of Second life, speculation with Linden dollars is controlled by the company, who can change the quantity of money in circulation as it wants and decide how to allocate these resources. Therefore, in the traditional metaverses, speculation with exchange rates can be "partially controlled" due to (i) the existence of a unique unidirectional flow or (ii) centralisation in the case of bidirectional flow. Metaverses in the Web3 are based on virtual currency schemes with bidirectional flow and decentralised economy, given the nature of public blockchains. These metaverses could be, indeed, prone to financial speculation since (i) they allow the activity of any speculator that is not interested in the main content of the virtual world, and (ii) the absence of a "central bank", who does not guarantee the stability of the exchange rate, benefits the speculators' activity. Consequently, the decentralised economy used by current social and gaming metaverses in the Web3 could generate unnecessary volatility for their users.

3. Data

In this section, we described the data used for the empirical analysis. In Sec. (3.1), we focused on the financial sphere and economic governance by describing data related to the cryptocurrency financial market, while in Sec. (3.2), we described data connected with the underlying activity in the NFT marketplace, which belong to the real sphere and metaverse commerce.

3.1. Economic governance: Metaverse fungible tokens

To analyse economic governance, we used daily price series from the CoinGecko database (CG, 2022), which is defined as a proper cryptocurrency data source including most of the trading activity in the cryptocurrency market (see Vidal-Tomás, 2022b). In particular, following CoinGecko and Coinmarketcap categories, we considered 196 metaverse tokens between October 28, 2017, and August 1, 2022, since the first metaverse token, MANA from Decentraland, was introduced on October 28, 2017. We also individually studied metaverse projects that incorporate play-to-earn games (i.e. tokens are classified in both categories), given that some metaverses evolved from (or towards) this blockchain gaming concept. The resulting sub-sample included 88 metaverse & play-to-earn tokens. We also employed the CCi30 index (CCi30, 2022), which is defined as a cryptocurrency market capitalisation-weighted benchmark, to represent the general behaviour of the cryptocurrency market from October 28, 2017, to August 1, 2022.[8]

To study the connectedness between economic governance and metaverse commerce, we created an equally-weighted (EW) market with the metaverse tokens at our disposal, thus we could describe the general evolution of this particular sector by using a unique time series.[9] Finally, as our case studies, we used individually SAND and MANA time series. In

[8] We employed this index since it has been widely used in the cryptocurrency literature (see e.g. Manahov, 2020 and Vidal-Tomás, 2022a).

[9] The equally-weighted market is a time series of returns that includes all the tokens with the same weight, i.e. $r_{t,m} = \sum_i^n r_{t,i}/n$, where n is the number of tokens and $r_{t,i}$ denotes each token (i) log-return at time t.

the last two cases, we employed the same sample periods as the available NFT data in Sec. (3.2).

For all our time series, we computed daily log returns, whose descriptive statistics are shown in Table 1 and Table 2.[10] As can be observed, this niche was characterised by a negative tendency, in which MANA and SAND represented the bright side (Table 2).

Table 1: Descriptive statistics of daily log-returns for all the tokens in the median, and the CCi30 index.

Category (median)	Tokens	Observations	Mean	Std.Dev.	Skewness	Kurtosis	Min.	Max.
Metaverse	196	336	-0.0048	0.1034	0.7311	9.5420	-0.4879	0.6169
Metaverse and play-to-earn	88	328	-0.0077	0.1009	0.7120	10.6485	-0.4701	0.5820

Crypto benchmarck	Observations	Mean	Std.Dev.	Skewness	Kurtosis	Min.	Max.
CCi30	1738	0.0005	0.0469	-1.2983	9.9761	-0.4845	0.1957

Table 2: Descriptive statistics for the equally-weighted metaverse market, MANA, and SAND.

Crypto indices	Sample period	Observations	Mean	Std.Dev.	Skewness	Kurtosis	Min.	Max.
EW Metaverse market returns	19/03/2018 - 01/08/2022	1597	-0.0011	0.0519	-1.1063	7.8641	-0.5101	0.2145
MANA returns	19/03/2018 - 01/08/2022	1597	0.0016	0.0761	1.2999	21.4952	-0.6536	0.9248
SAND returns	02/12/2019 - 01/08/2022	717	0.0042	0.0942	0.9714	7.9978	-0.4674	0.7131

3.2. Metaverse commerce: NFTs

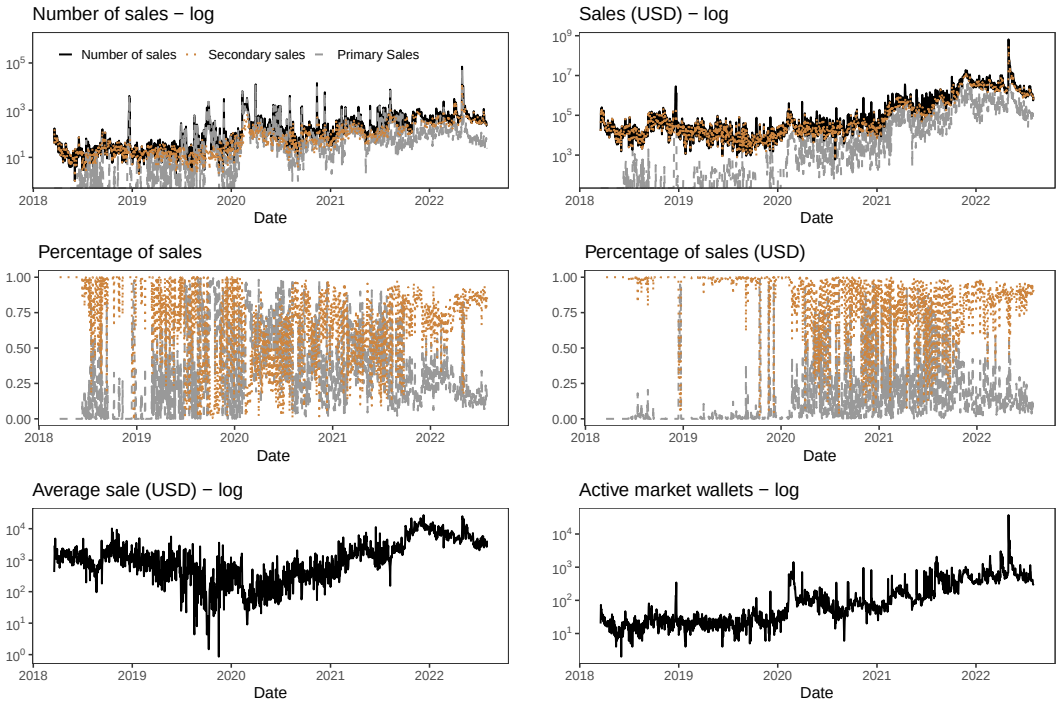
To represent metaverse commerce, we used specific NFT data from the entire metaverse industry, which was provided by nonfungible.com (see Dowling, 2021a,b, Vidal-Tomás, 2022a): (i) number of (total) sales, (ii) sales in US dollars (USD), (iii) average sale (USD), (iv) active market wallets, (v) primary sales, (vi) secondary sales, (vii) primary sales (USD) and (viii) secondary sales (USD).[11] The corresponding dataset is depicted in Fig. (3), from March 19, 2018 to August 1, 2022, according to the availability of NFT data.[12] Interestingly, we observed the speculative behaviour in the NFT market given the high values reported by the secondary sales and secondary sales (USD) since the end of 2021. In particular, we underlined (i) an increasing trend in secondary sales to the detriment of primary sales, (ii) a positive evolution of the average sale (USD), and (iii) the growth of active market wallets and sales. Moreover, we also highlighted the crash of the bubble in the NFT marketplace due to the negative tendency in the average price (USD) and sales (USD), since its maximum at the end of 2021, with a decrease in value equal to -84.61% and -95.35%, respectively. The only period in which the generalised negative tendency was broken is identified on May 1, 2022, given the NFT activity reported by the new metaverse project "Otherside". This event did not revert the negative scenario, given that the market suffered from a decrease higher than 99% in number of sales, sales (USD) and active wallets, since May 1, 2022.[13] Nevertheless, it is relevant to note that sales and active wallets showed a positive long-term tendency, which is similar to the positive long-term performance of fungible cryptos, like Bitcoin or Ethereum.[14]

[10] The graphical representation of the descriptive statistics for all the tokens is included in the supplementary material.
[11] The number of (total) sales includes primary and secondary sales. Following Nadini et al. (2021), we refer to the first time an asset is sold as the asset's primary sale. For consistency, we mainly used the same names as provided by nonfungible.com.
[12] Descriptive statistics are included in the supplementary material.
[13] In the Appendix, Sec. (9.3), we showed the higher decrease in sales (USD) and active wallets, when excluding the impact of Otherside.
[14] In the supplementary material, we showed all the NFT variables without log-transformation.

Fig. (3) also provided us with two interesting properties regarding the NFT marketplace. First, the dynamics of the number of sales and sales in US dollars is different. Second, NFT sales include a difference percentage of secondary and primary sales over time. These two facts are relevant for scholars given that (i) the results of a given study could be different if academics used the number of sales or sales in USD and (ii) the decomposition of NFT sales in primary and secondary sales could shed more light on the properties of this market.

Last but not least, it is interesting to note that the average sale (USD) at the beginning of 2020 was close to zero, after a period of considerable NFT activity. Hence, in the future, we could observe again a market situation in which NFTs are traded with prices that are close to zero. This conjecture is supported by the research agenda in Lee et al. (2021) and Momtaz (2022). The former stated that the existence of NFT-related defraud could deter potential buyers and disincentive creators, which coincides with George Akerlof's 'market of lemon'. The latter considered that the possibility of creating "infinite digital resources would push prices to zero".

Figure. 3: Evolution of the NFT features in the metaverse industry.



3.3. Case studies: Decentraland and The Sandbox

As reported by Nadini et al. (2021), traders seem to be specialised in the NFT market, given that they performed at least 73% of their transactions in a specific NFT category; for instance, art, collectables, games, metaverse or utility categories. Given that this feature could be also observed internally in each particular category, we focused on the main metaverse projects: Decentraland (MANA) and The Sandbox (SAND). Interestingly, in line with Nadini et al. (2021), we report in Table (3) that these two specific projects mainly represented most of the total sales and sales (USD) in the metaverse for the sample period analysed.[15] Indeed, in 2021, Decentraland and The Sandbox represented on average the

[15] In the supplementary material, we show graphically the market share of both metaverses over time.

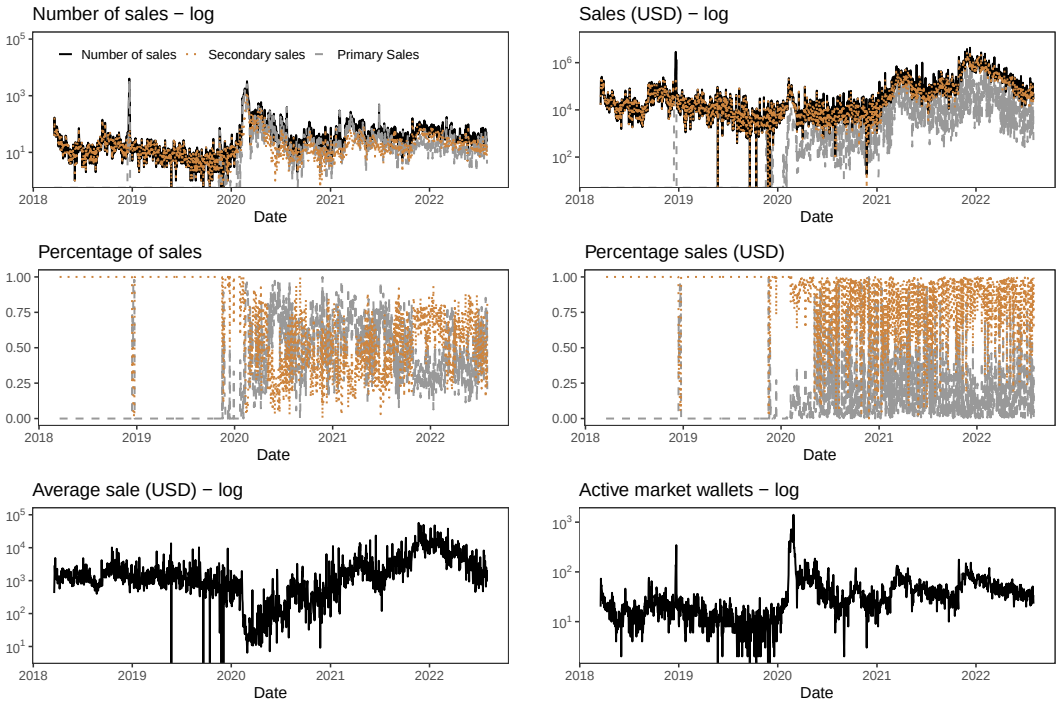
66.39% and 66.51% of the NFT total sales and sales (USD), respectively. Since May 1, 2022, their dominance in the market is shared with Otherside. Given its nascent stage, we shed some light on this project in Sec. (6.2), for future research.

Table 3: Percentage of sales related to Decentraland and The Sandbox on average by year.

	Number of sales				Sales (USD)		
Year	Decentraland	The Sandbox	Both	Year	Decentraland	The Sandbox	Both
2018	88.68%	0.00%	88.68%	2018	99.10%	0.00%	99.10%
2019	43.43%	1.88%	45.31%	2019	84.48%	0.65%	85.14%
2020	51.06%	29.35%	80.40%	2020	41.79%	15.91%	57.70%
2021	23.92%	42.47%	66.39%	2021	30.72%	35.79%	66.51%
2022	9.93%	14.44%	24.36%	2022	11.00%	21.66%	32.65%

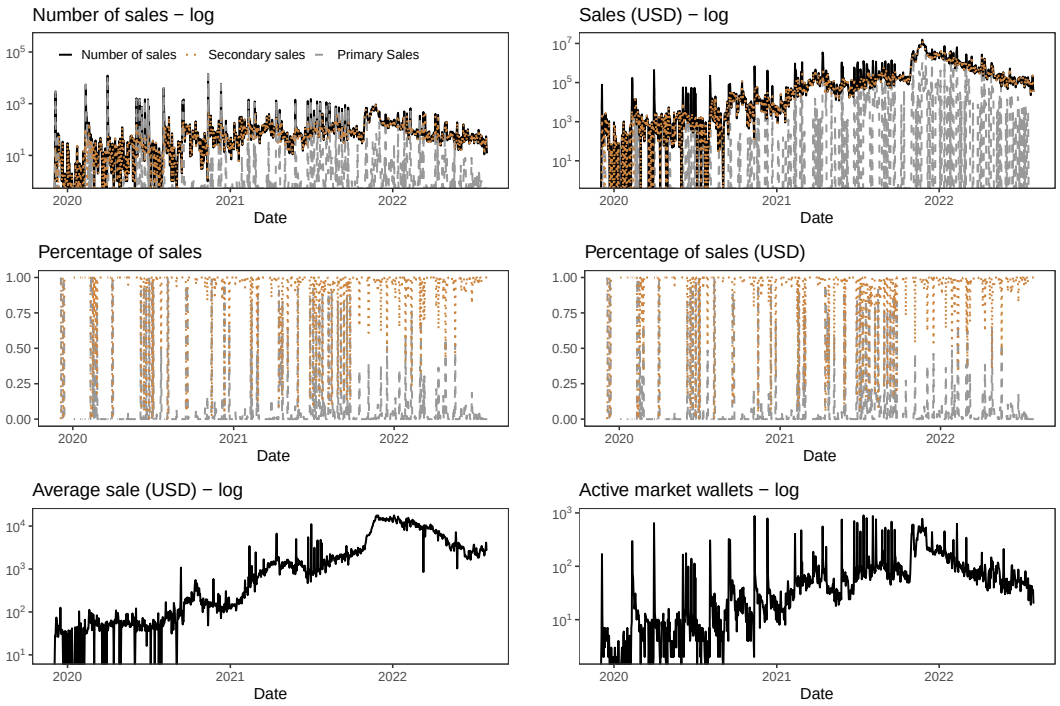
Fig. (4) shows data related to Decentraland, from March 19, 2018, to August 1, 2022, while Fig. (5) reports data related to The Sandbox, from December 2, 2019 to August 1, 2022.[16] In both cases, we identified the rise and fall of these markets in 2022, with a decrease in NFT sales (USD) equal to -98.84% and -99.78% for Decentraland and The Sandbox, respectively. In line with previous results for the entire metaverse industry, we observed again a different dynamics for number of sales and sales (USD), underlining the need of considering both variables when analysing the NFT marketplace. Moreover, the evolution of primary and secondary sales in Decentraland and The Sandbox is completely different, which highlights the individuality of each metaverse, i.e. scholars should analyse separately the properties of each metaverse.

Figure. 4: Evolution of the NFT features in Decentraland.



[16] Descriptive statistics are included in the supplementary material.

Figure. 5: Evolution of the NFT features in The Sandbox.



4. Methodology

In this section, we briefly described the methodology to analyse the metaverse niche. For the sake of space, a detailed description is provided in the Appendix, Sec. (9.4).

On the one hand, to assess the current state of economic governance (i.e. **H1/H3/H4**), we used (i) the Backward Sup Augmented Dickey-Fuller test (BSADF) -also known as PSY test- and (ii) the buy-and-hold (abnormal) returns, described in Sec. (9.4.1) and Sec. (9.4.2), respectively. PSY test allowed us to analyse whether metaverse tokens displayed unit of account and medium of exchange properties by examining the (in-)existence of explosive dynamics. The absence of bubbles will support the properties of metaverse tokens as unit of account and medium of exchange. However, the continuous existence of explosive dynamics will undermine these properties, thus metaverse tokens could not be used as currencies. Buy-and-hold (abnormal) returns allowed us to examine store of value properties. Positive buy-and-hold returns ($\overline{BHR}_\tau$) will support store of value properties, and positive buy-and-hold abnormal returns ($\overline{BHAR}_\tau$) will also underline a better performance compared to the cryptocurrency market, represented by the CCi30 index.

On the other hand, in addition to the previous descriptive analysis for the NFT marketplace, we employed the wavelet coherence approach, Sec. (9.4.3), to evaluate the current state of metaverse commerce by analysing its connectedness with the metaverse financial market. With this approach we analysed whether the underlying economic activity represented by NFT features (real sphere) drove the evolution of fungible tokens (financial sphere), or vice-versa (i.e. **H2/H5/H6**). As described in Sec. (9.4.3), given the available data and their statistical properties, (i) we applied the wavelet coherence approach to study the connectedness between metaverse market returns and the growth rate of NFT features, when

analysing the entire metaverse, while (ii) we analysed the relation between MANA/SAND prices and NFT raw values, when considering our two case studies focused on Decentraland and The Sandbox.

5. Empirical results

In Sec.(5.1) and Sec.(5.2), we show the results connected with economic governance and the role of metaverse tokens as medium of exchange, unit of account and store of value (i.e. **H1/H3/H4**), while the outcome regarding the connectedness between metaverse commerce and economic governance (i.e. **H2/H5/H6**) is presented in Sec.(5.3).

5.1. BSADF - PSY test

Fig. (6) reports the number and percentage of tokens in the metaverse industry characterised by explosive dynamics according to the PSY test and considering the 90% (solid black line), 95% (dashed grey line) and 99% (dotted tan line) critical value. Fig. (7) reports the periods in which the PSY test identified the bubble phenomenon in MANA and SAND tokens.

In Fig. (6), we observed that, since 2020, the metaverse industry was described by an almost continuous explosive dynamics given the generalised presence of bubbles in the market. More specifically, until 2022 and considering the 90% critical value, we detected the maximum number of bubbles on October 30, 2021, with 36 tokens (27% of the sample), in the case of the metaverse, and on November 2, 2021, with 16 tokens (27% of the sample), in the case of the metaverse & play-to-earn niche. Indeed, on average, November 2021 was identified as the month with more bubbles, with 25 metaverse tokens (17%) and 10 metaverse & play-to-earn tokens (17%). This outcome could be related to the fact that Facebook rebranded its name as Meta on October 2021. However, we observed that, in percentage, March 2021 was also identified as an explosive period since we detected bubbles in the 40% (21 tokens) of the metaverse sector and 49% (5 tokens) of the metaverse & play-to-earn niche. Despite the fact that the growth of the sector [see Fig. (1)] reduced the percentage of bubbles at the end of 2021, we still observed an almost continuous presence of explosive dynamics. These findings reported in the metaverse industry were supported by the volatile behaviour of MANA and SAND in Fig. (7), where we identified the longest bubble periods in March and November 2021.

Interestingly, after January 1, 2022, we identified a very short period in which the PSY test detected explosive behaviour in a significant portion of the metaverse. Indeed, on May 12, 2022, we observed a flash crash on 63 metaverse tokens (34%) and 30 metaverse & play-to-earn tokens (36%) as a consequence of the Terra-Luna collapse (Briola et al., 2022) and Tether depegging (Somraaj, 2022). Considering the nature of any flash crash (Turiel and Aste, 2022), its effect on the market progressively disappeared on May 13, 2022. This short event can be also easily identified in Fig. (7), with MANA and SAND tokens.

With these results we underline that the explosive behaviour is not only detected in the main metaverse projects, such as MANA and SAND, but it is a generalised characteristic of this niche. Due to this fact, Web3 metaverse tokens could not be used as unit of account and medium of exchange, given the explosiveness observed over time. In other words, they could not be used as currencies in the metaverse, since those firms that would accept these tokens would have to recalculate prices very frequently; a process that would be costly to the seller and confusing to the meta-user.

Figure. 6: Number and percentage of bubbles detected by the BSADF/PSY test considering the 90% (solid black line), 95% (dashed grey line) and 99% (dotted tan line) critical value.

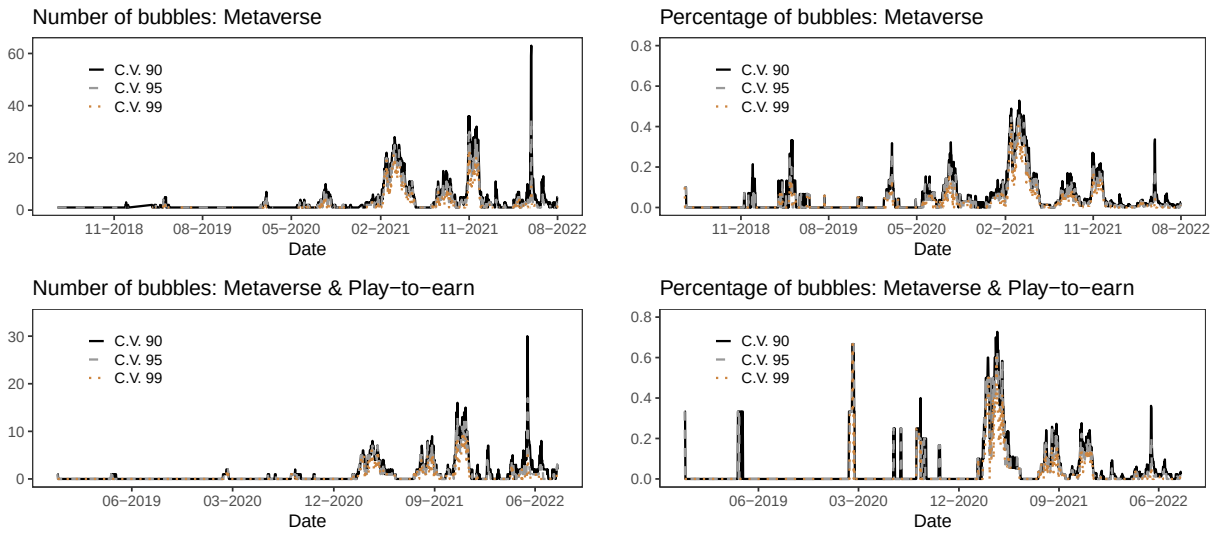
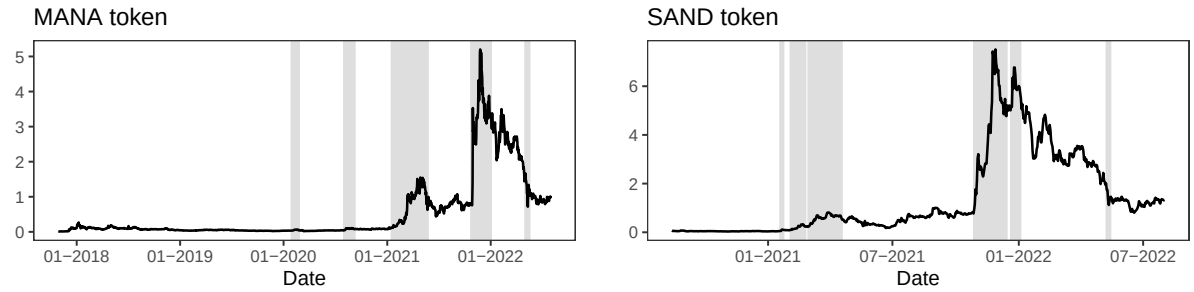


Figure. 7: MANA/SAND prices (black line) and bubbles detected by the BSADF/PSY test considering the 90% critical value (grey areas).



5.2. Buy-and-hold (abnormal) returns

Table 4 and Table 5 report the long-run performance of metaverse and metaverse & play-to-earn tokens, respectively, for different holding periods τ.[17] First, the market included large out-performers due to the considerable difference between the mean, which was positive, and the median, which was negative. Second, these niches showed an unstable performance given the changing $\overline{BHR}_\tau/\overline{BHAR}_\tau$, for different holding periods τ; specifically the difference between $\tau = 1$ year and $\tau =$ Entire sample. Third, in the median, both niches showed a negative (or zero) performance regardless of the holding period, which should prevent meta-users from entering this new crypto-sector. Indeed, we report in Table 6 a considerable difference between $\overline{BHR}_\tau/\overline{BHAR}_\tau$ on November 30, 2021 (peak of the metaverse bubble[18]) and $\overline{BHR}_\tau/\overline{BHAR}_\tau$ on the last day of our sample, August 1, 2022. In particular, a meta-user observed how the positive performance of their tokens (in the median), with $\overline{BHR}_\tau$ equal to 240.73%/198.45% for metaverse/metaverse & play-to-earn projects, disappeared in 8 months, obtaining a negative performance equal to -81.48%/-90.23%. This finding highlights the fast transition from

[17] We included in the supplementary material a graphical representation of the long-run performance through histograms.

[18] For simplicity, we used November 30, 2021 as the reference for the most speculative period since, (i) November was the most volatile month by number of bubbles before 2022, and (ii) MANA and SAND had their maximum prices on November 25, 2021 and November 28, 2021, respectively.

an insane bull market in 2021, as was reported by Maouchi et al. (2021) and Vidal-Tomás (2022a), to its crash in 2022. Considering this outcome, metaverse tokens cannot be used as store of value since users cannot expect to receive the same economic value that the token was worth when they acquired them. Indeed, meta-users held currencies that, in the median, lost the 80% and 90% of their initial value.

Considering the results reported in Sec.(5.1) and Sec.(5.2) for the entire metaverse niche, we can contend that the Web3 meta-economy includes metaverse tokens that do not work as currencies from the economic perspective, since (i) the presence of explosive behaviour do not support their function as unit of account and medium of exchange; and (ii) the negative performance does not allow users to hold these tokens as store of value. Therefore, we rejected **H1**.

Table 4: Long-run performance of metaverse tokens.

	$\overline{BHR}_\tau$						
Metaverse	1 week	1 month	3 months	6 months	9 months	1 year	Entire sample
Mean	0.3596	0.7978	1.6339	3.6430	4.0804	13.0660	1.7454
Std. Error	(0.1101)	(0.2484)	(0.4127)	(1.4487)	(2.1593)	(10.6344)	(0.8551)
Median	-0.0407	-0.0663	-0.3201	-0.4027	-0.4437	-0.1955	-0.8148
Std. Error	(0.0346)	(0.0827)	(0.1015)	(0.1169)	(0.1359)	(0.2316)	(0.0447)
% of tokens: $BHR > 0$	0.4388	0.4821	0.4278	0.3820	0.3916	0.4348	0.2245
Tokens	196	195	194	178	143	92	196

	$\overline{BHAR}_\tau$						
Metaverse	1 week	1 month	3 months	6 months	9 months	1 year	Entire sample
Mean	0.3445	0.7779	1.6150	3.5337	3.8748	12.3516	2.0086
Std. Error	(0.1105)	(0.2463)	(0.4026)	(1.4363)	(2.1393)	(10.5854)	(0.8396)
Median	-0.0498	-0.0122	-0.1433	-0.2401	-0.1744	-0.0704	-0.2918
Std. Error	(0.0353)	(0.0509)	(0.0516)	(0.0717)	(0.0679)	(0.1380)	(0.0225)
% of tokens: $BHAR > 0$	0.4235	0.4872	0.3969	0.4101	0.4126	0.4674	0.2755
Tokens	196	195	194	178	143	92	196

Table 5: Long-run performance of metaverse & play-to-earn tokens.

	$\overline{BHR}_\tau$						
Metaverse & play-to-earn	1 week	1 month	3 months	6 months	9 months	1 year	Entire sample
Mean	0.2197	0.4910	1.2269	2.3959	5.6193	29.5149	2.3169
Std. Error	(0.1410)	(0.1851)	(0.4761)	(1.1184)	(4.6049)	(27.9386)	(1.7970)
Median	-0.0712	-0.0028	-0.3438	-0.4853	-0.6363	-0.3482	-0.9023
Std. Error	(0.0694)	(0.1003)	(0.1373)	(0.1250)	(0.1887)	(0.3155)	(0.0270)
% of tokens: $BHR > 0$	0.4318	0.5000	0.3908	0.3253	0.3438	0.3714	0.1818
Tokens	88	88	87	83	64	35	88

	$\overline{BHAR}_\tau$						
Metaverse & play-to-earn	1 week	1 month	3 months	6 months	9 months	1 year	Entire sample
Mean	0.2142	0.4739	1.2440	2.4021	5.6616	29.0758	2.7704
Std. Error	(0.1415)	(0.1776)	(0.4589)	(1.0676)	(4.5574)	(27.8063)	(1.7699)
Median	-0.0308	-0.0092	-0.1444	-0.2579	-0.2279	-0.0180	-0.2886
Std. Error	(0.0658)	(0.0859)	(0.1110)	(0.0693)	(0.0792)	(0.2736)	(0.0239)
% of tokens: $BHAR > 0$	0.4432	0.4886	0.3793	0.3494	0.3594	0.4857	0.2386
Tokens	88	88	87	83	64	35	88

Table 6: Long-run performance on 30 November 2021 and 1 August 2022 for metaverse and metaverse & play-to-earn tokens.

	Metaverse		Metaverse & Play-to-earn	
$\overline{BHR}_\tau$	30/11/2021	01/08/2022	30/11/2021	01/08/2022
Mean	24.1605	1.7454	28.6432	2.3169
Std. Error	(7.3088)	(0.8551)	(15.4618)	(1.7970)
Median	2.4073	-0.8148	1.9845	-0.9023
Std. Error	(0.8852)	(0.0447)	(0.6788)	(0.0270)
% of tokens: $BHR > 0$	0.7628	0.2245	0.8209	0.1818
Tokens	156	196	67	88
$\overline{BHAR}_\tau$	30/11/2021	01/08/2022	30/11/2021	01/08/2022
Mean	22.7833	2.0086	27.9547	2.7704
Std. Error	(7.2544)	(0.8396)	(15.3669)	(1.7699)
Median	1.9142	-0.2918	1.8131	-0.2886
Std. Error	(0.5473)	(0.0225)	(0.5879)	(0.0239)
% of tokens: $BHAR > 0$	0.6923	0.2755	0.7612	0.2386
Tokens	156	196	67	88

On the other hand, the impact of large out-performers in this market could be underlined by the positive behaviour of SAND and MANA in Table 7, whose tendency in the long-run was also observed in the previous Fig. (7). Given this positive long-term price, some practitioners and scholars could argue that SAND and MANA were characterised by store of value properties. For instance, focusing on Bitcoin, Baur and Dimpfl (2021) stated that "it can be argued that the price did not fall over sufficiently long periods and that Bitcoin shows store of value properties". However, regardless of the general positive performance over time, we kept observing continuous high price fluctuations. Indeed, MANA and SAND suffered from a decrease in value equal to -81% and -82%, respectively, since their maximum price in November 2021. Consequently, considering the existing literature, we observed that MANA and SAND displayed some store of value properties, given their positive performance in the long-run. Nevertheless, meta-users should also consider the risk regarding the high price fluctuations.[19]

Table 7: Long-run performance of MANA and SAND tokens.

	BHR_τ							
Tokens	1 week	1 month	3 months	6 months	9 months	1 year	Entire sample	30/11/2021
MANA	0.1432	0.7448	12.4936	11.4842	11.9794	6.1885	99.7529	455.7069
SAND	-0.3372	-0.3911	-0.4722	0.8525	4.7509	6.6009	15.4360	82.4157
	$BHAR_\tau$							
Tokens	1 week	1 month	3 months	6 months	9 months	1 year	Entire sample	30/11/2021
MANA	-0.0243	0.1838	9.8192	10.0076	11.3209	6.1192	98.4429	449.8316
SAND	-0.3439	-0.2834	-0.4366	-0.9087	-0.2520	3.9798	14.8034	78.5565

Analysing all the results connected with SAND and MANA, in Sec.(5.1) and Sec.(5.2), we conclude that both metaverse tokens do not work as currencies from the economic perspective, since they cannot be employed as unit of account and medium of exchange, given their explosive dynamics. Hence, we rejected **H3** and **H4**.

[19] Unlike Baur and Dimpfl (2021), Yermack (2015) considered that the high volatility cannot be neglected even with positive trends. In their study focused on Bitcoin, they stated that "holding bitcoins even for a short period is quite risky, which is inconsistent with a currency acting as a store of value".

5.3. Wavelet coherence approach

5.3.1. Metaverse

In Fig. (8), we report the wavelet coherence between the metaverse financial market, represented by the EW metaverse market returns, and the growth rate of each NFT feature, corresponding to the entire metaverse marketplace.[20] Through this approach, we identified three relevant findings. First, we observed a low co-movement between market returns and NFT features, given the dominance of the blue colour, except for some red areas. Interestingly, the high co-movement seems to appear since 2020, around some explosive periods, which are underlined by grey dotted lines. This result is in line with Aharon and Demir (2021), who observed that NFTs[21] are mainly independent of shocks from other assets classes (e.g. gold, oil, bonds, equity market, Ethereum) during normal times.

Second, we observed that the growth rate of total sales, primary sales, secondary sales, average (USD) and active wallets were less relevant than total sales (USD), primary sales (USD) and secondary sales (USD) in order to describe the dynamics of market returns due to their lower co-movement. In other words, we observed more blue areas in number of sales, average (USD) and active wallets, compared to sales in USD. Therefore, scholars should focus their studies on sales in USD to analyse potential dependences with the financial markets. Indeed, we detected that total sales (USD) and secondary sales (USD) were the most relevant variables due to the existence of red areas since 2020 over the 64-day and 256-day frequency bands, i.e. specifically, we found dependences in the long-run. Our results are also in line with the literature given that the NFT market is characterised by sale heterogeneity, in which "the average sale price of NFTs is lower than 15 dollars for 75% of the assets, and larger than 1594 dollars, for 1% of the assets" (Nadini et al., 2021). The similar causal structure between "metaverse market returns - secondary sales" and "metaverse market returns - active wallets" supports the fact that most of the activity (active wallets) was related to many transactions at low prices.[22]

Third, in terms of causality, we observed that (i) the financial market was generally driven by the NFT market, represented by total sales, total sales (USD), primary sales, primary sales (USD), secondary sales, secondary sales (USD) and active wallets over the 64-day frequency band; (ii) more specifically, fungible metaverse tokens (financial sphere) were mainly driven by metaverse commerce (real sphere), represented by total sales and secondary sales USD, since 2020 over the 64-day and 200-day frequency bands; and (iii) most of the co-movements between metaverse returns and NFT features were positive. Interestingly, an exception is identified in Average (USD) since March 2021, over the 256-day frequency band. In this case, we observed that the price of each NFT was driven by the performance of the financial cryptocurrency market.[23] Consequently, the high prices reported in the NFT market could be explained by the positive evolution of the metaverse fungible tokens in the financial market.

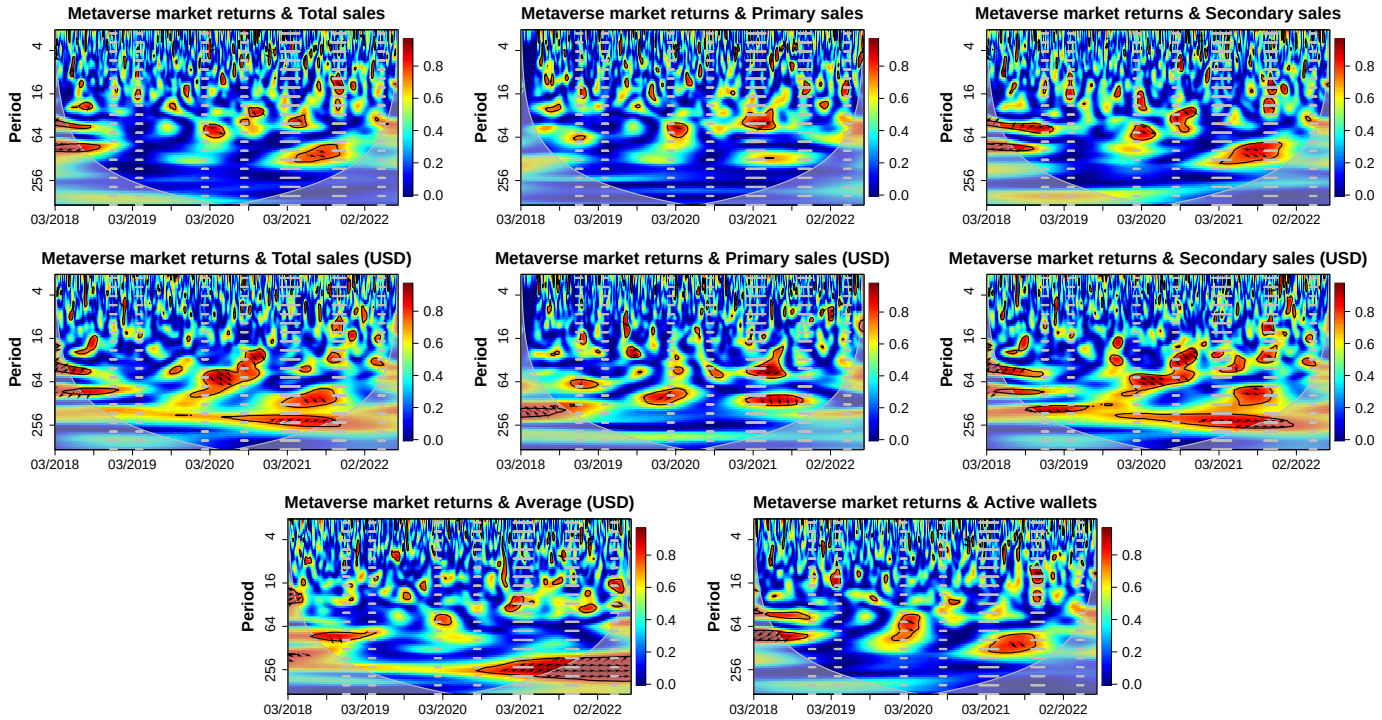
[20] We excluded the analysis of metaverse & play-to-earn tokens in this section, given that NFT data strictly includes all the trades in the metaverse. Thus, the proper comparison is the one that relates metaverse returns to NFT transactions in the metaverse.

[21] It is relevant to underline that, compared to this study, they analysed the entire NFT market (collectible, art, utility, gaming, metaverse, etc.), without being focused on the metaverse niche.

[22] As proof of this, in the Appendix, Fig. (13), we report the different connectedness between "active wallets - secondary sales" and "active wallets - secondary sales (USD)" where we observed that active wallets drove the evolution of the number of secondary sales, but not secondary sales in USD.

[23] This point was also supported by the dependences reported in "metaverse market returns - total sales (USD)" and "metaverse market returns - secondary sales (USD)", over the 256-day frequency band, when metaverse returns drove the dynamics of sales in USD.

Figure. 8: Wavelet coherence between metaverse market returns and growth rates of NFT features from the entire metaverse marketplace. Grey dotted lines identifies explosive dynamics in the metaverse niche, according to the BSADF/PSY test.



Considering the results reported in this subsection, we observed that the fungible and non-fungible market were not related most of the time. However, when the connectedness arose, specially during volatile periods, the financial market was generally driven by the NFT activity in the metaverse marketplace. More specifically, in 7 out of 8 NFT variables, the metaverse commerce mainly influenced the evolution of fungible tokens. As a result, we state that the agent's consumption behaviour is based on the real sphere of the metaverse, thus, the economic governance (or financial sphere) is driven by the metaverse commerce (or real sphere). Specifically, total sales (USD) and secondary sales (USD) were the main variables that described the evolution of metaverse token prices. Given this fact, we can also affirm that the interest of users on the metaverse concept was genuine, and based on the underlying activity of the metaverse, i.e., they were not attracted to the metaverse due to the financial performance of the cryptocurrency market. Therefore, we did not reject **H2**. However, we need to underline that metaverse market returns drove the evolution of NFT prices in the long-run since 2021. Consequently, prices in the NFT marketplaces were affected by the speculation arisen from the cryptocurrency market, which highlights the speculative component and the risk of trading with NFTs.

5.3.2. Decentraland (MANA) & The Sandbox (SAND)

In Fig. (9)/(10), we report the wavelet coherence between MANA/SAND prices and the NFT features from their specific metaverse marketplaces, Decentraland/The Sandbox.

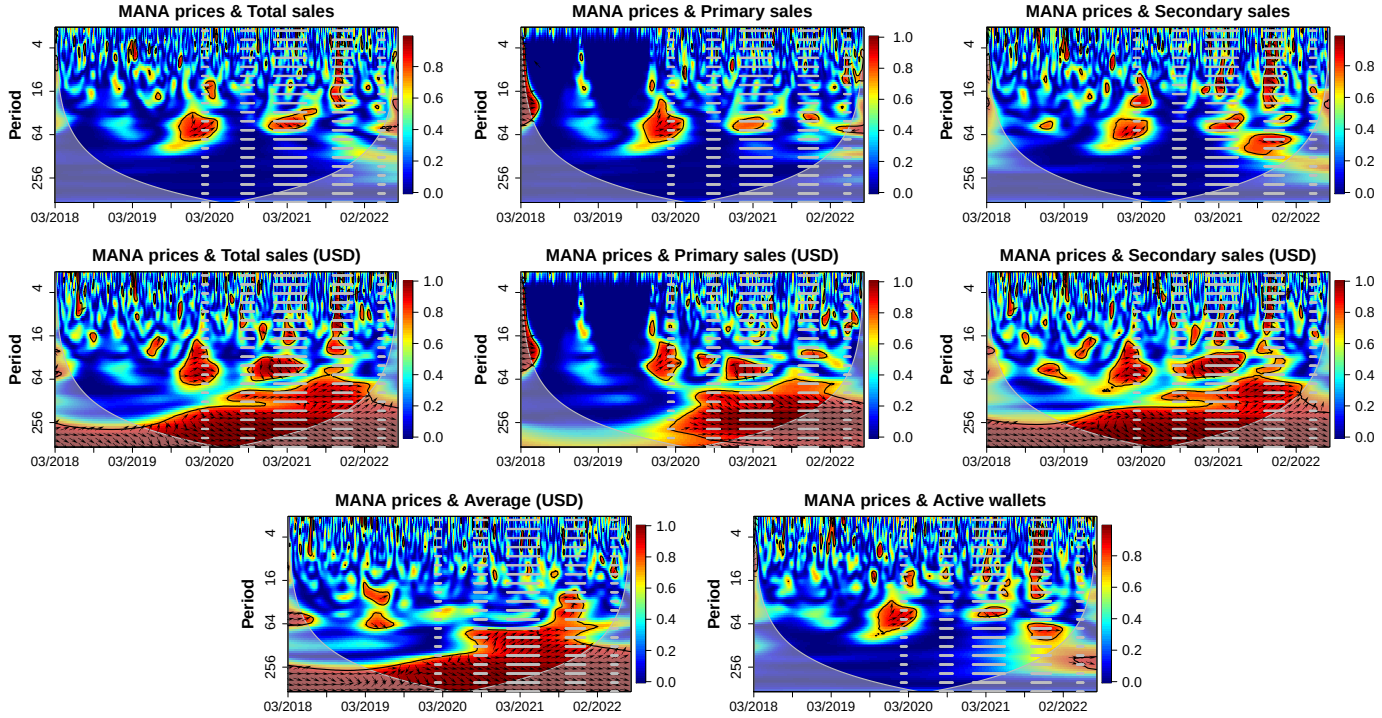
Focusing on Fig. (9), we detected the following properties related to MANA and Decentraland. First, in line with the general behaviour of the metaverse, we observed that, for most of the sample period, the financial market was not connected with the real market, represented by NFT sales, active wallets and prices. However, since 2020, we identified

again some read areas that seem to appear around the explosive dynamics of the financial market, which is represented by grey dotted lines.

Second, total sales (USD), primary sales (USD) and secondary sales (USD) were the most significant variables to describe the performance of market returns, which is in line with previous results, due to the predominance of red areas compared to the rest of variables. Consequently, we reaffirm the fact that academics should also use sales in USD when examining potential dependences with the cryptocurrency market and the corresponding metaverse tokens, instead of being exclusively focused on NFT prices (see Dowling, 2021a,b, Aharon and Demir, 2021 and Bao and Roubaud, 2022).

Third, most of the activity (active wallets) was related to many transactions at low prices given the similar causal structure between "MANA prices - secondary sales" and "MANA prices - active wallets".[24]

Figure. 9: Wavelet coherence between MANA prices and NFT features from the Decentraland marketplace. Grey dotted lines identifies explosive dynamics in MANA, according to the BSADF/PSY test.



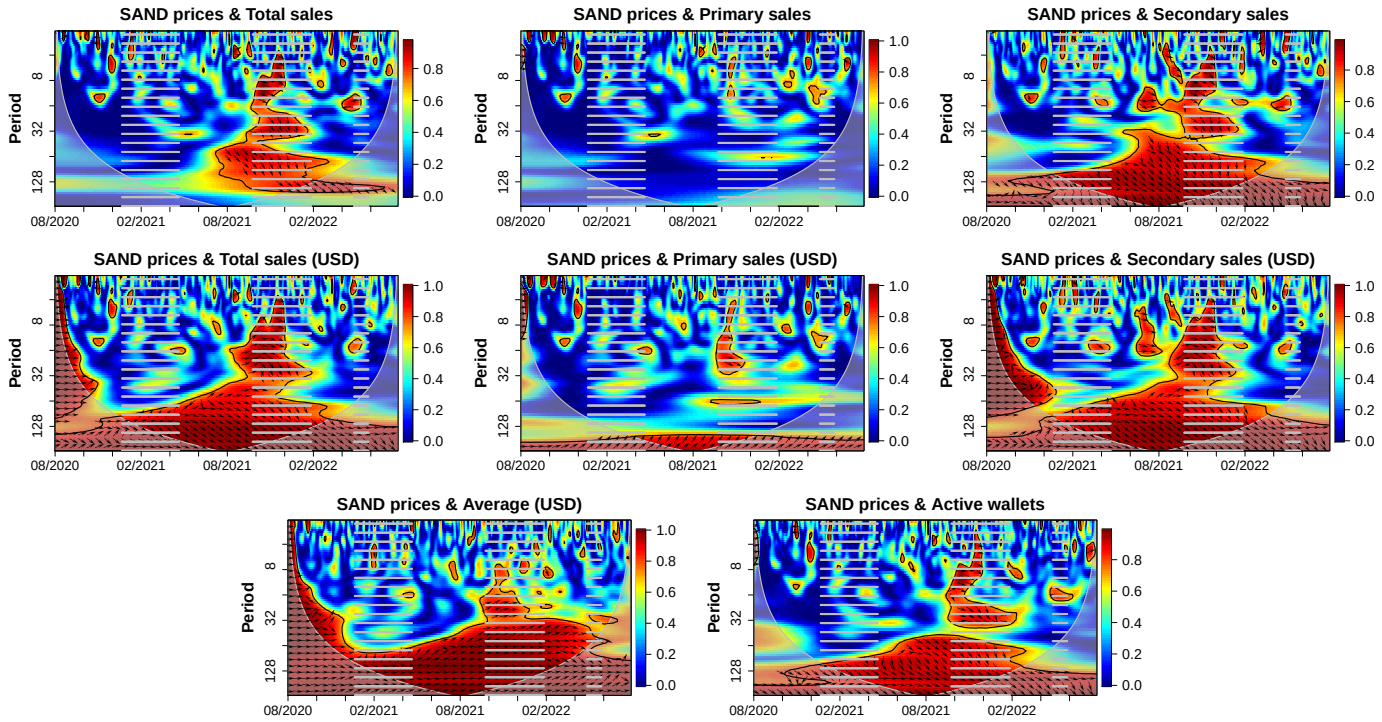
Finally, in terms of causality, we identified a switching dynamics over time. We underlined three different phases. In 2020, we observed that MANA prices mainly explained the evolution of the NFT marketplace, over the 64-day frequency band. The result of this period is supported by Dowling (2021b), who observed that, in March 2020, Ethereum was leading the Decentraland marketplace. Thus, cryptocurrencies influenced the NFT market during the first stage of this metaverse. In 2021, however, we noticed that the NFT features mainly explained the evolution of MANA prices. Finally, in 2022, we observed that in the short-run (over the 4/16-days frequency bands) MANA prices were driven by the NFT activity during a very short period, while in the long-run (over the 100-days frequency bands) MANA prices drove the NFT activity in the Decentraland marketplace; specifically, in the cases of total sales (USD), secondary sales (USD) and average (USD). Given

[24] As proof of this, and in line with Fig. (13), we observed in Fig. (14) that the number of secondary sales was driven by active wallets.

this switching dynamics, we could not reach a clear conclusion about **H5**, since the dominance of the real and financial sphere changed over time in Decentraland. At any rate, we did highlight the presence of a speculative component given the effect of MANA on the NFT activity during some periods. In particular, and in line with the behaviour of the entire metaverse (Fig. 8), the influence of the financial market was detected with the relation "MANA prices - Average (USD)" over the 64-day frequency band, since NFT prices evolved according to MANA prices in the long-run.

On the other hand, SAND token and The Sandbox metaverse in Fig. (10) reported clear results regarding the connectedness between economic governance and metaverse commerce. First, scholars should use total sales (USD), secondary sales (USD), average (USD) and active wallets in their analysis focused on SAND, given their relevance to describe the financial market. Second, in terms of causality, NFT activity in The Sandbox drove the evolution of SAND prices, specially during the bubble in November 2021, which underlines the relevance of the real sphere over the financial sphere. Therefore, we did not reject **H6**. However, in line with the entire metaverse and Decentraland, it is relevant to underline that the speculative component in The Sandbox was also observed in "SAND prices - Average (USD)", since SAND prices influenced NFT prices, over the 24 and 64-days frequency band at the end of 2021. Last but not least, we underline that The Sandbox seems to be less prone to the effect of the financial market than Decentraland.

Figure. 10: Wavelet coherence between SAND prices and NFT features from the The Sandbox marketplace. Grey dotted lines identifies explosive dynamics in SAND, according to the BSADF/PSY test.



6. Robustness analysis

6.1. Relative volatility

In Sec.(5.1) and Sec.(5.2), we have observed the explosive behaviour that characterises all the tokens in the Web3 metaverse niche. To shed more light on this point, we studied whether the volatility of Web3 metaverse tokens was lower

than the volatility of fiat currencies (GBP/USD, EUR/USD, JPY/USD) and a relevant token used in the Web2 (WoW token/USD). We selected WoW token since it is the virtual currency used in the largest MMORPG, World of Warcraft, with 120 million subscribers.[25]

Following the traditional financial literature (Engle, 2004; Koopman et al., 2005; Patton, 2011), we used square returns as a proxy of daily volatility. Average volatility is reported in Table (8) where we noticed that the magnitude of fluctuations in the Web3 metaverse tokens was not comparable with GBP, EUR, JPY and WoW token. Indeed, the main metaverse tokens, MANA and SAND, reported volatility values that were two orders of magnitude higher than all the fiat currencies, and one order of magnitude higher than WoW token. Indeed, we observed that, on average, the volatility of all the Web3 metaverse tokens was three orders of magnitude higher than fiat currencies.

Table 8: Average volatility for fiat currencies, WoW token, and metaverse tokens.

	Fiat currency			Web2	Web3 - Cryptocurrency			
Sample period	GBP	EUR	JPY	WoW token	Metaverse	Metaverse & P2E	MANA	SAND
02/12/2019 - 01/08/2022	0.000031	0.000017	0.000020	0.000230	0.017836	0.014050	0.005779	0.008878

In a similar line to Baur and Dimpfl (2021), we also applied two-sample Wilcoxon test to examine whether there was any metaverse token whose volatility was lower than the volatility reported by fiat currencies and WoW token, i.e. $H_0 : \sigma^2_{\text{metaverse}} \leq \sigma^2_{\text{fiat/WoW}}$. Using the Wilcoxon test, we rejected the previous statement for the 196 tokens, since we could not find any Web3 metaverse token whose volatility was lower than GBP, EUR, JPY and WoW token, at the 1% significance level.[26] This robustness test supports our previous hypotheses **(H1/H3/H4)**, since fiat currencies and Web2 tokens seem to be better candidates as "currencies", than the existing Web3 tokens. In other words, developers and companies interested in the metaverse could simply use fiat currencies, or reliable collateralised stablecoins pegged to fiat currencies. Therefore, at present, Web3 metaverse tokens do not offer a suitable alternative to traditional fiat currencies.

6.2. Otherside & Apecoin

In Sec. (3), we have observed that Decentraland and The Sandbox lost their dominance in the metaverse niche in favour of Otherside. In this subsection, we provided a brief description of this metaverse.

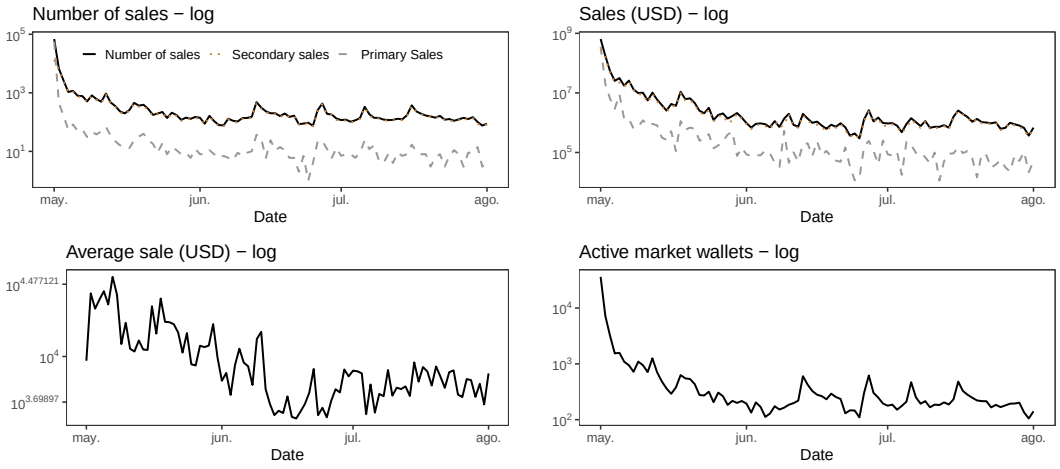
Bored Ape Yacht Club (BAYC) is a collection of 10,000 ape-themed NFTs with unique traits and characteristics. This collection was created by Yuga Labs in April 2021, being recognised as one of the most valued NFT projects (Beganski, 2022). As proof of this, a set of 101 NFTs from the BAYC was sold for $24.4 million (Beer, 2021). To foster its growth in the crypto-space, Yuga Labs created its own metaverse platform, namely, Otherside. This metaverse blends mechanics from massively multiplayer online RPGs and web3-enabled virtual worlds. The native currency adopted by Otherside for its economy and ecosystem is ApeCoin (APE), which was launched in March 2022. Despite its nascent stage, Otherside became the largest metaverse by sales, and APE became the largest Web3 metaverse token by market capitalisation. More specifically, in July 2022, Otherside, Decentraland and The Sandbox represented the 65%, 10% and 12% of sales volume

[25] Data for GBP, EUR, and JPY were sourced from Yahoo Finance, while data for WoW token were sourced from wowtokenprices.com.
[26] We included in the supplementary material a graphical representation of all the p-values reported by the Wilcoxon test.

in the metaverse, respectively. In this line, APE, MANA and SAND led the metaverse niche with a market cap equal to $1.5, $1.2 and $1.1 billions, respectively.

The impact of Otherside in the metaverse was clear during its release on April 30 at 12 pm. As can observed in Fig. (11), on its first day there were 68,917 sales, with a value equal to $646,056,885. However, since that day, Otherside suffered from a decrease in sales and sales (USD) equal to -99.89% and -99.61%.[27] Interestingly, this decrease was not relevant in terms of market share. In Table 9, we observed that Otherside overtook Decentraland and The Sandbox in 2022.[28]

Figure. 11: Evolution of the NFT features in Otherside.



Focusing on its native currency, APE, we observed in Table 10 that it shared the same destiny as the rest of metaverse tokens.[29] Indeed, APE decreased its value in 21.90%, even though it outperformed the CCi30 index. Consequently, we even detected a negative tendency in the newest and largest metaverse project, which could underline the decreasing interest in this kind of project.

Table 9: Percentage of sales related to Decentraland, The Sandbox and Otherside on average by year.

	Number of sales					Sales (USD)			
Year	Decenraland	The Sandbox	Otherside	Sum	Year	Decenraland	The Sandbox	Otherside	Sum
2018	88.68%	0.00%	0.00%	88.68%	2018	99.10%	0.00%	0.00%	99.10%
2019	43.16%	1.88%	0.00%	45.04%	2019	84.48%	0.65%	0.00%	85.14%
2020	51.06%	29.35%	0.00%	80.40%	2020	41.79%	15.91%	0.00%	57.70%
2021	23.92%	42.47%	0.00%	66.39%	2021	30.72%	35.79%	0.00%	66.51%
2022	9.93%	14.44%	30.26%	54.62%	2022	11.00%	21.66%	29.19%	61.84%

With this simple descriptive analysis, we highlight the need of analysing Otherside in the near future, since it has become the largest metaverse project with the largest cryptocurrency. Moreover, it is relevant to consider that the emergence of new relevant metaverse projects seems to significantly decrease the activity in old metaverses, thus users should consider the risk of holding NFTs from specific metaverses in the long-run due to possible depreciation.

[27] With the exception of the first day, most of the sales were secondary sales.
[28] In the supplementary material, we show graphically the market share of these metaverses over time.
[29] In the supplementary material, we reported the PSY test applied on APE. Results showed a bubble on May 2022, which coincides with the launch of Otherside NFTs.

Table 10: Long-run performance of APE token.

APE	1 week	1 month	3 months	6 months	9 months	1 year	Entire sample
BHR	0.5562	0.4297	-0.5749				-0.2190
BHAR	0.4690	0.3921	-0.0007				0.2429

7. Discussion

7.1. Stablecoins, fiat currencies, and permissioned blockchains

In this paper we have analysed all the Web3 metaverse tokens in the market, i.e. 196 tokens. These tokens were characterised by a continuous emergence of bubbles, with a volatility higher than traditional fiat currencies and tokens used in MMORPGs, like the WOW token. This outcome underlines the fact that most of the metaverse projects are not launching metaverse tokens as currencies, but only as speculative assets, given that they cannot be used as medium of exchange or unit of account. The best examples can be found in MANA and SAND since, even though they do not display medium of exchange and unit of account properties, investors could use them as store of value given their positive long-term trend.

As we stated in Sec. (2.3.2), the bidirectional virtual scheme used in Web3 metaverses could give rise to speculation since (i) they allow the activity of any speculator that is not interested in the main content of the virtual world, and (ii) the absence of a "central bank", who does not guarantee the stability of the exchange rate, benefits the speculators' activity. The fact of rejecting **H1/H3/H4** supports these statements due to the excessive explosiveness in this niche. Consequently, developers should consider proper alternatives that provide their metaverses with reliable virtual currencies and schemes that could reduce the excessive volatility.

On the one hand, fiat currencies or collateralised stablecoins pegged with fiat currencies could be used as native currencies for the metaverse. First, the intrinsic volatility of the cryptocurrency market would be avoided. Thus, users in the metaverse could hold their virtual currencies without being worried about high price fluctuations and the loss of value. Second, related to **H2/H5/H6**, the cryptocurrency market could not affect NFT prices due to the absence of a fungible metaverse token as a native currency. In other words, exchanging Web3 metaverse tokens for stablecoins or fiat currencies could delete links that foster speculation into the NFT marketplace. Finally, the absence of Web3 tokens could attract users that are only interested in the gaming and social experience, since the option of speculating with the native metaverse token would not exist.

On the other hand, in a similar line to the bidirectional flow scheme with a central authority (Second life), developers could use permissioned blockchains to create a metaverse with restrictions. Permissioned blockchains are blockchains that have an access control layer, which allows participants to perform the actions that they are authorized to perform. A central authority could regulate the virtual economy, guaranteeing the stability of the system and minimising the speculation in the market. This system is characterised by beneficial features since permissioned networks also make proper use of blockchain, such as utilizing its decentralized nature for data storage. However, regulations bring censorship to the network, which stops the permissioned network from making the most out of the whole blockchain concept based on decentralisation.

7.2. Web2 vs Web3

The results obtained in our paper have shown that metaverses in the Web3 are prone to speculation given (i) the explosive behaviour of Web3 metaverse tokens, (ii) and the influence of these tokens on the NFT prices in the long-run.

Interestingly, we could contend that current Web3 metaverses are similar to old MMORPGs in the 00s, where the business part of the metaverse was more relevant than the game part. Compared to Web2 metaverses in 2022, Web3 metaverses are not characterised by an organic engagement that retains players in the game. Indeed, in these platforms "the ability to purchase NFTs or in-game currency effectively creates pay-to-win game mechanics, a quality that most major franchises and successful games avoid." (Nystrom, 2022). For the last 20 years, the most famous MMORPGs developed the game part of their metaverses and controlled the business part by reducing the shadow economy, speculation and proposing attractive monthly subscription plans. Indeed, to address RMT issues, most of the companies, like Blizzard (WoW) since 2015, decided to include in-game digital currencies ("WoW token") allowing users to exchange fiat currency for in-game currency (Beikverdi, 2015). Moreover, they also allowed users to buy high-level avatars and equipment at a fixed price. As a consequence, at present, the main companies involved in Web2 metaverses (i) include the shadow economy into the virtual economy, connecting legally the virtual and real world, and (ii) reduce the speculation by "deleting" the old "tedious cycle". On the contrary, Web3 metaverses only rely on the business part of the metaverse (speculation) without real improvements regarding organic engagement. As stated by Reynolds (2022), "it's impossible to determine how many of these players are there just for fun, rather than as employees of guilds playing the game to earn yield for investors." Developers interested in a sustainable metaverse could introduce measures to reduce speculation, such as collateralised stablecoins or a minimum regulation. The absence of these features could indicate that developers are only interested in the business part of the metaverse, avoiding the development of the gaming part. Therefore, compared to Web2 metaverses, we could contend that metaverses in the Web3 are mainly created for speculative purposes.

On the other hand, following the basic Bloomfield's concept, we must underline that another obvious difference between these metaverses is found on the "the technical part" of the metaverse, mainly, Web2 and Web3 infrastructure. Blockchain technologies and DeFi could offer some benefits for the meta-economy, such as, (i) efficient data storage (Lee et al., 2021), (i) proof-of-ownership of digital assets (Chalmers et al., 2022), (ii) reduction of intermediation costs (Bellavitis et al., 2022), (iii) decentralisation of the economy (Duan et al., 2021), (iv) royalties on secondary trades of NFTs to creators (Moy and Gadgil, 2022), (v) absence of shadow market (Momtaz, 2022) or (vi) solution against fraud due to the verifiability (Wang et al., 2021). However, it also presents some drawbacks and contradictions: (i) there are cases in which the seller does not actually own the item to which the NFT relates (Mendis, 2021), (ii) crypto's hacking problems (Howcroft, 2022), (iii) presence of speculation (Vidal-Tomás, 2022a), (iv) concentration of decision power in the hands of large coin-holders (Auer et al., 2021) and (v) same service as traditional finance with familiar vulnerabilities, such as leverage, liquidity mismatches and their interaction through profit-seeking and risk-management practices (Aramonte et al., 2021). Therefore, we observe that Web3 infrastructure shows strong potential, however, as stated by Chalmers et al. (2022), "for all the excitement around blockchain, there is a growing disillusion that many use-cases have been revealed as nothing more than technological solutionism." Indeed, it could not be necessary to use decentralised data storage since users are not interacting with most of the main Web3 metaverses. According to Dappradar, the number of monthly users

in the gaming metaverse Axie infinity in April 2022 was around 100,000 users, while social metaverses like Decentraland and The Sandbox were struggling with 10,000 users (see also Reynolds, 2022). However, Blizzard Entertainment gaming titles (mainly, WoW) reported 27 million monthly active users in the second quarter of 2022 (Statista, 2022); and social metaverses like Second life and Horizon Worlds reported 500,000 (Heath, 2022) and 300,000 (Olson, 2022) monthly active users in the first quarter of 2022. A recent survey commissioned by blockchain entertainment provider Coda Labs (Coda Labs, 2022) highlighted that traditional gamers are more interested in playing a "fun game" than the tokenomics associated with many Web3 metaverses (Huigsloot, 2022). The survey data suggested that users were not attracted to this niche due to the following points: (i) not sure how this type of gaming would work, (ii) don't have a cryptocurrency account or wallet set up, (iii) higher likelihood to be scammed, (iv) too expensive to get started and (v) too new or risky. Therefore, and paradoxically, metaverses like Axie infinity, Decentraland and The Sandbox could not even need blockchain technologies, in terms of data storage, given their low activity and number of transactions.

Web3 infrastructure could be a relevant factor to consider for future stages of the metaverse. However, at present, the decentralised economy is only used to foster speculation. Moreover, some benefits of blockchain, such as decentralised data storage, are not needed due to the low interest in Web3 metaverses.

7.3. Future research

Most of the existing literature on the metaverse has focused on (i) extended, augmented, and virtual reality technologies (Biener et al., 2022), (ii) underlying infrastructure (Yang et al., 2022), (iii) social applications (Duan et al., 2021), NFT marketplaces (Nadini et al., 2021) and (iv) surveys or research agendas on the state of the art (Lee et al., 2021, Momtaz, 2022). However, due to the nascent interest in this research field, gaps in the literature still exist. First, in a similar line to Initial Coin Offering (ICO) literature (Lyandres et al., 2022; Vidal-Tomás, 2021), scholars should analyse the success determinants of the metaverse projects, which would be beneficial for investors and meta-users. Second, the increasing number of metaverses and limited audience in the Web3 underline the need of analysing the users' behaviour when migrating from one metaverse to another. As observed with the emergence of Otherside, to the detriment of Decentraland and The Sandbox, the metaverse niche could be characterised by being a winner-take-all market where only a particular metaverse will survive. Third, related to the previous point, scholars should analyse the success of Otherside and APE, shedding more light on its marketplace and also token properties. Forth, some metaverses with play-to-earn mechanisms were boosted by the emergence of boss/employee relationships, where a "manager" hired workers from developing countries (e.g. Philippines, Venezuela, and Thailand) (Nunley, 2021). Consequently, it could be interesting to study whether users interacted with the metaverse for gaming or business reasons. Fifth, despite the bear market in the Web3 metaverse niche, venture financing for the blockchain industry remained robust, since blockchain games and metaverse projects raised a cumulative $1.3 billion in venture capital between July and September 2022 (Bourgi, 2022). This point suggests that venture capital could be focused on the long-term value proposition of this niche, thus scholars should keep analysing the properties of this market in the future.

8. Conclusion

Compared to the existing literature, which is mainly focused on the analysis of particular metaverses and NFT collections [e.g. Decentraland (Dowling, 2021a), Cryptopunks (Nguyen, 2022) and Axie infinity (Nadini et al., 2021]), in this study we have considered the entire Web3 metaverse niche, i.e. both (i) the entire metaverse marketplace (ii) and the 196 available metaverse fungible tokens. Moreover, when analysing our particular case studies (Decentraland and The Sandbox), we have examined all the available NFT features (sales, sales in USD, NFT price and active wallets), while most of the studies were only focused on a specific variable, especially, average NFT prices (see Dowling, 2021a,b, Nadini et al., 2021, Bao and Roubaud, 2022). This paper also provided a review to discuss the different aspects of the development of the metaverse in the recent decades.

Considering the entire metaverse in the Web3, Decentraland and The Sandbox, we have examined the current state of the meta-economy by analysing economic governance and metaverse commerce. As described in the introduction, we studied six hypotheses. Two of them applied on the entire metaverse and four of them based on our case studies. On the one hand, using the BSADF/PSY test and buy-and-hold (abnormal) returns, we rejected **H1/H3/H4**, since (i) the explosive dynamics is a generalised property of the metaverse niche and (ii), in the median, metaverse tokens suffered from a decrease in price around 80-90%. MANA and Decentraland showed a positive long-term trend, which could support some store of value properties. However, they could not be used as unit of account and medium of exchange given their explosive behaviour. For robustness purposes, using Wilcoxon test, we compared the volatility of Web3 metaverse tokens to fiat currencies and the WoW token. Our results showed that the 196 tokens are characterised by a higher volatility. Consequently, companies and developers should consider fiat currencies or collateralised stablecoins as native currencies in the future, since metaverse fungible tokens are prone to explosiveness. To the best of our knowledge, this is the first study analysing the role of the existing Web3 metaverse tokens as currencies from the economic perspective.

On the other hand, through the wavelet coherence approach, we analysed **H2/H5/H6**. Considering the entire metaverse **(H2)** and The Sandbox **(H6)**, we observed that the evolution of fungible tokens was driven by the metaverse commerce, in 7 out of 8 NFT variables [specifically, total, primary & secondary sales, total, primary & secondary sales in USD, and active wallets]. In the case of Decentraland **(H5)**, we did not observe a conclusive result given the switching dynamics, i.e. the influence of the financial market on the NFT marketplace changed over time. Therefore, we could not reject **H2** and **H6**. This result could be considered a good sign for the future of the metaverse since the agent's consumption behaviour is mainly based on the real sphere of the metaverse. Unfortunately, we also observed that financial markets affected NFT prices in all the cases analysed. Consequently, speculation in the cryptocurrency market could give rise to overvalued/undervalued NFTs, according to the mood of speculators. Developers should face this issue by considering different alternatives to remove this speculative link, such as the implementation of stablecoins or permissioned blockchains.

Given the explosive behaviour of the native currencies in all the metaverse, and the influence of these tokens on the NFT prices in the long-run, we can state that, at present, the metaverse is only an illusion. Indeed, developers seems to be more interested in the speculative part of the metaverse, since the native currencies cannot be used as unit of account or medium of exchange. Metaverse tokens are only speculative assets that alter NFT prices in the marketplace. The only

positive note is that the interest of the community in the metaverse is genuine, i.e. wallet activity, sales and sales in USD were not driven by the financial market. However, this interest is decreasing over time, regardless of the metaverse (Decentraland, The Sandbox or Otherside).

The results shown in this study underline the questions of who will be building the metaverse, startups or incumbents (Momtaz, 2022), and how will be built the metaverse, Web2 or Web3 infrastructure. It is complex to state who will lead the revolution in the metaverse, since giant incumbents, such as Meta, Alphabet or Microsoft, could create their own metaverses with a sound and proper virtual economy, based on fiat currencies and traditional trading systems.[30] In order to compete with incumbents and Web2 metaverses, crypto-start ups should improve the organic engagement and introduce alternative cryptocurrency options to create a reliable currency that can be adopted by millions of users. At any rate, in 2022, the metaverse is falling short of expectations, both in the Web2 and Web3, due to the decreasing activity in all the metaverse platforms (Capoot, 2022). Consequently, given the current interest and existing technology, the transition to living in virtual worlds could take years, if not a couple of generations. In the end, it seems that the hype has run far ahead of reality.

Acknowledgements

The author acknowledges the financial support from the Margarita Salas postdoctoral contract MGS/2021/13 (UP2021-021) financed by the European Union-NextGenerationEU.

9. Appendix

9.1. Appendix: Unit of account, medium of exchange and store of value

Money is a unit of account as it serves the purpose of measuring the value of any product, i.e. consumers must treat it as a numéraire when comparing the prices of alternative retail goods (Walras, 2013; Yermack, 2015). If the value of a virtual currency in terms of other (fiat) currencies changes abruptly on a day-to-day basis, sellers and buyers would need to recalculate prices very frequently, which would derive into a costly and confusing procedure. In this line, the unit of account and the medium of exchange feature cannot be separated (White, 1984); if the virtual currency is not accepted widely by retailers and customers as a means of payment, the unit of account will not exist. Virtual currencies could be considered a medium of exchange if they would allow frictionless transactions between buyers and sellers. However, actors must convert virtual currencies into local currencies, and vice-versa, for different purposes (e.g. paying taxes or creditors), which involves exchange rate risk that increases with the level of volatility in the market (Baur and Dimpfl, 2021). Finally, to be considered a store of value, the owner of a virtual currency expects to receive the same (or higher) economic value that the currency was worth when he acquired it (Yermack, 2015). The extreme market volatility could affect the long-run performance of any currency and its ability as store of value. For instance, Baur and Dimpfl (2021) observed that Bitcoin price did not fall over sufficiently long periods, showing store of value properties, while Yermack (2015) stated that Bitcoin

[30] As stated by Momtaz (2022), the fact "that incumbents are resistant to building the public version of the Metaverse is evident, given that this would imply the sharing of their data and opening interfaces to enable cross-dApp interoperability."

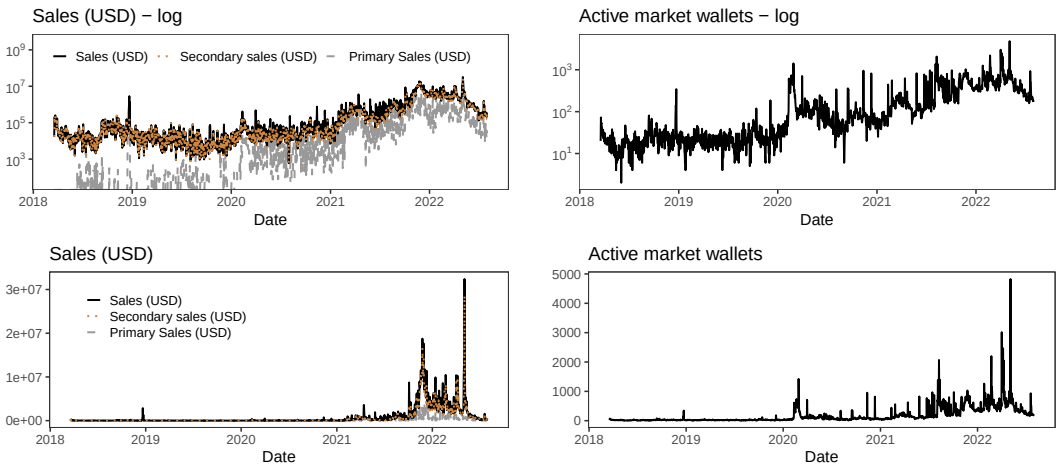
high volatility undermines its function as store of value. Therefore, a positive performance in the long-run supports store of value properties, even though it would be undermined by an extreme volatility.

9.2. Appendix: Alternative hypotheses

- **(H1A)** The meta-economy includes metaverse tokens that do not work as currencies from the economic perspective, since the explosive behaviour and negative performance do not support their function as unit of account, medium of exchange and store of value.
- **(H2A)** The agent's consumption behaviour is based on the financial sphere of the metaverse, thus, the metaverse commerce (real sphere – NFT features) is driven by the economic governance (financial sphere - fungible token prices/returns). In this scenario, users are only attracted to the metaverse given the raising speculation in the financial cryptocurrency market, and they do not have any real interest in the activity of the metaverse.
- **(H3A/H4A)** Decentraland/the Sandbox does not include metaverse tokens (namely, MANA/SAND) that work as currencies from the economic perspective, since the explosive behaviour and negative performance do not support their function as unit of account, medium of exchange and store of value.
- **(H5A/H6A)** The agent's consumption behaviour in Decentraland/The Sandbox is based on the financial sphere, thus, the metaverse commerce (real sphere – NFT features in the Decentraland/The Sandbox marketplace) is driven by the economic governance (financial sphere - MANA/SAND prices).

9.3. Appendix: Sales (USD) and active wallets in the metaverse excluding Otherside

Figure. 12: Evolution of sales in USD and active wallets in the metaverse industry, excluding Otherside.



9.4. Appendix: Methodology

9.4.1. BSADF - PSY test

We used the methodology proposed by Phillips and Shi (2020) (see also Phillips et al., 2015), namely BSADF test, also known as PSY real-time bubble detection method, to analyse the bubble phenomenon in the metaverse industry, SAND

and MANA tokens. In the context of our paper, the absence of bubbles will support the properties of metaverse tokens as unit of account and medium of exchange. However, the continuous existence of explosive dynamics will undermine these properties, thus metaverse tokens could not be used as currencies.

With the PSY test, it was possible to identify explosive price behaviour in financial markets through sup ADF tests applied on a backward expanding sample sequence.[31] More specifically, this technique is based on an ADF model specification but uses flexible time window in its implementation to consider time-varying dynamics and structural breaks. The null hypothesis of the PSY test captures normal market behaviors and states that prices follow a martingale process with a mild drift function,

$$y_t = g_T + y_{t-1} + u_t, \tag{1}$$

where $g_T = kT^{-\gamma}$ (with constant $k, \gamma > 1/2$, and sample size T) captures any mild drift that could exist in prices. The regression model chosen by Phillips and Shi (2020) is

$$\Delta y_t = \mu + \rho y_{t-1} + \sum_{j=1}^{p} \phi_j \Delta y_{t-j} + v_t, \tag{2}$$

where the regression error v_t follows $v_t \overset{i.i.d}{\sim} \left(0, \sigma^2\right)$. The p lag terms of Δy_t consider potential serial correlation, and is selected by BIC. The regression model nests the null hypothesis as a special case with $\mu = g_T$ and $\rho = 0$. The ADF statistic is the t-ratio of the least squares estimate of ρ. The main feature of this methodology is that the recursive evolving algorithm allows real-time identification of explosive periods while also allowing for the presence of multiple structural breaks. In other words, the PSY procedure computes the ADF statistic recursively from a backward expanding sample sequence, considering r_1 and r_2 as the start and end points of the regression sample. Consequently, the ADF statistic calculated for this period is denoted by $ADF_{r_1}^{r_2}$. Following the nomenclature proposed by Phillips and Shi (2020), the end point of all the samples is $r_2 = r^\dagger$ while the start point r_1 can change within a plausible range, $\left[0, r^\dagger - r_0\right]$, where r_0 is the minimum window, and equal to $r_0 = 0.01 + 1.8/\sqrt{T}$. The PSY statistic is the supremum (Sup) taken over the values of all the ADF statistics in the entire recursion, i.e.

$$PSY_{r^\dagger}\left(r_0\right) = \sup_{r_1 \in [0, r^\dagger - r_0], r_2 = r^\dagger} \left\{ADF_{r_1}^{r_2}\right\} \tag{3}$$

Phillips and Shi (2020) defined the origination/termination date of a bubble as the first observation whose backward sup ADF statistic exceeded/fell below the critical value. Therefore, the estimated origination and termination dates (denoted by $\hat{r}_e$ and $\hat{r}_f$) are then given by:

$$\begin{aligned} \hat{r}_e &= \inf_{r^\dagger \in [r_0, 1]} \left\{ r^\dagger : PSY_{r^\dagger}\left(r_0\right) > cv_{r^\dagger}\left(\beta_T\right) \right\}, \\ \hat{r}_f &= \inf_{r^\dagger \in [\hat{r}_e, 1]} \left\{ r^\dagger : PSY_{r^\dagger}\left(r_0\right) < cv_{r^\dagger}\left(\beta_T\right) \right\}, \end{aligned} \tag{4}$$

where $cv_{r^\dagger}\left(\beta_T\right)$ is the $100\left(1 - \beta_T\right)$ critical value of the $PSY_{r^\dagger}\left(r_0\right)$ statistic, and β_T takes values 1%, 5%, 10%, i.e. 99%,

[31] In this paper, we used the BSADF/PSY test. Alternatively, it could be possible to use the generalised SADF test (GSADF), which is an ex post statistic used for analysing a given data set for bubble behaviour. However, given that the PSY test can be used by traders to detect bubbles in real time, we employed this method to underline the possible speculative strategies.

95% and 90% critical value.

9.4.2. Buy-and-hold (abnormal) returns

We used the average buy-and-hold returns ($\overline{BHR}_\tau$) to analyse the long-run performance of the fungible tokens, for different focal holding period (τ), since its first trading day. Following Momtaz (2021b), $\overline{BHR}_\tau$ was calculated as follows:

$$\overline{BHR}_\tau = \frac{1}{n}\sum_{i=1}^{n}\frac{P_{i,\tau} - P_{i,0}}{P_{i,0}}, \tag{5}$$

where $P_{i,0}$ represents opening prices in the first trading day and $P_{i,\tau}$ denotes closing prices after the focal holding period (τ). Considering the short life of most of the tokens, we employed the following holding periods: (i) one week, (ii) one month, (iii), three months, (iv) six months, (v) nine months, (vi) one year and (vii) all the sample period at our disposal, i.e. until 1 August 2022. In the case of MANA and SAND, we reported their individual BHR_τ.

We also calculated buy-and-hold abnormal returns by adjusting $\overline{BHR}_\tau$ with a market capitalisation-weighted benchmark to examine the performance of these tokens without the general tendency of the cryptocurrency market. In other words, average buy-and-hold abnormal returns ($\overline{BHAR}_\tau$) are defined as $\overline{BHR}_\tau$ less the market return, which is represented by the CCi30 market capitalisation index:

$$\overline{BHAR}_\tau = \frac{1}{n}\sum_{i=1}^{n}\left[\frac{P_{i,\tau} - P_{i,0}}{P_{i,0}} - \frac{P_{CCi30,\tau} - P_{CCi30,0}}{P_{CCi30,0}}\right], \tag{6}$$

where $P_{CCi30,0}$ is the same day as $P_{i,0}$. In this case, we also calculated the specific $BHAR_\tau$ for MANA and SAND.

Considering our hypotheses (**H1/H3/H4**), positive $\overline{BHR}_\tau$ will support store of value properties, and positive $\overline{BHAR}_\tau$ will also underline a better performance compared to the cryptocurrency market, represented by the CCi30 index.

9.4.3. Wavelet coherence approach

Following Dowling (2021b) and Vidal-Tomás (2022a), we shed some light on the connections between NFT features and Web3 fungible tokens by means of the wavelet coherence approach, in order to analyse the co-movement and causality between the two-time series in terms of both time and frequency domain. According to Torrence and Compo (1998), the cross wavelet transform of two time-series x_t and y_t is defined by means of the continuous wavelet transform $W_n^x(u,s)$ and $W_n^y(u,s)$, as follows:

$$W_n^{x,y}(u,s) = W_n^x(u,s) * W_n^y(u,s) \tag{7}$$

where u is associated to the location, s to the scale and $*$ denotes the complex conjugate. This measure identifies areas in the time-frequency domain where time series show a high common power. In other words, it shows the local covariance between the time series at each scale.

Having computed the cross wavelet transform, the wavelet coherence, which captures the co-movement between two time series in the time-frequency domain, is defined as:

$$R^2(u,s) = \frac{|S(s^{-1}W^{xy}(u,s))|^2}{S(s^{-1}|W^x(u,s)|^2)S(s^{-1}|W^y(u,s)|^2)} \tag{8}$$

where S is a smoothing operator over time as well as scale, and $0 \leq R^2(u,s) \leq 1$ (Rua and Nunes, 2009). Values close to 0 indicate the absence of correlation, while values close to 1 indicates a high correlation. Nevertheless, unlike the standard correlation coefficient, the wavelet squared coherence is restricted to positive values. As a consequence, it is not possible to identify positive and negative co-movements properly. To overcome this issue, we employed the phase difference proposed by Torrence and Compo (1998) that allowed us not only to distinguish between positive and negative co-movements but also to shed some light on the causal relationships between time series. Wavelet coherence phase difference is defined as:

$$\psi_{x,y}(u,s) = tan^{-1}\left(\frac{\Im\{S(s^{-1}W^{xy}(u,s))\}}{\Re\{S(s^{-1}W^{xy}(u,s))\}}\right) \tag{9}$$

where, $\Im$ and $\Re$ are the imaginary and real parts of the smoothed cross-wavelet transform, respectively.

One of the main properties of this methodology is that it "can be used to analyse time series that contain nonstationary power at many different frequencies" (Torrence and Compo, 1998) (see also Daubechies, 1990). This fact was also supported by Cazelles et al. (2008) when contending that the wavelet coherence approach is "especially relevant to the analysis of non-stationary systems, like those observed in ecological systems." Wavelet analysis demonstrated to be a powerful tool widely used throughout science and engineering. Consequently, given its versatility and attractiveness, financial practitioners and researchers started to use it to analyse economic and financial time series (see Gençay et al., 2001). In our particular case, this was a relevant feature that allowed us to analyse connectedness between our time series, since (i) NFT data are non-stationary and (ii) we could not compute (stationary) NFT growth rates due to the existence of many zeros in different variables (e.g. sales, sales (USD) or active wallets) for Decentraland and The Sandbox case studies.[32] The wavelet approach allowed us to overcome this issue, for our two case studies, by analysing directly the connectedness between MANA/SAND prices and NFT raw values, which are non-stationary, without being necessary to calculate returns / growth rates. On the other hand, when considering the entire metaverse niche, we did analyse the connectedness between metaverse market returns and NFT growth rates, since the entire metaverse is represented by equally-weighted market returns and there was no a considerable problem with the existence of zeros in the NFT variables, given that we considered the 100% of NFT transactions.[33] Therefore, (i) we applied the wavelet coherence approach to study metaverse market returns and the growth rate of NFT features, when analysing the entire metaverse, while (ii) we analysed the relation between MANA/SAND prices and NFT raw values, when considering our two case studies focused on Decentraland and The Sandbox.[34]

In the figures that report the wavelet coherence analysis, the x-axis indicates the time domain component, while the y-axis indicates the frequency component, from lower levels of scale, which refer to high frequency variations, up to higher levels of scale, which refer to low frequency variations. The degree of coherence is related to different colours: from blue

[32] The existence of zeros is related to periods of inactivity in the NFT marketplaces. The computation of growth rates would gave rise to the indeterminate form 0/0.

[33] The only exceptions are, especially, primary and primary sales (USD) when we observed some zero values. In this case we replaced zeros with ones, since it will not affect the final result due to their concentration at the beginning of the sample.

[34] Alternatively, when analysing Decentraland and The Sandbox, it could be possible to compute growth rates after replacing zero values with ones for all the NFT variables. Thus, we compared MANA/SAND returns to the growth rates of NFT variables. Indeed, after the substitution, we observed consistent results with those observed in the main text [see supplementary material]. Nevertheless, in order to minimise changes in data, we reported those results obtained analysing the connectedness between prices and NFT raw values.

(low coherence/co-movement) to red (high coherence/co-movement). Arrows indicate phase differences, which underlines the synchronization between the two series. On the one hand, arrows pointing to the right (left) indicate time series that are in-phase (out of phase); that is, they are positively (negatively) correlated. On the other hand, arrows pointing upward indicate that the first time series leads the second; whereas downward pointing arrows indicate that the second time series is leading the first. Consequently, with the figures showing the wavelet coherence, we were able to analyse whether metaverse fungible tokens were driven by the underlying economic activity in the metaverse, represented by NFT features, or vice-versa (i.e. **H2/H5/H6**). Finally, we plotted grey vertical lines that identify those days in which the PSY test detected the bubble phenomenon. More specifically, when analysing the entire metaverse industry, the grey vertical lines show that more than the 20% of the metaverse tokens were characterised by speculative behaviour. However, when focusing on the specific cases of Decentraland (MANA) and The Sandbox (SAND), we underlined with the grey vertical lines the explosive periods detected by the PSY method for these particular cases.

9.5. Appendix: Wavelet coherence analysis

Figure. 13: Wavelet coherence between growth rates of (i) active market wallets & secondary sales and (ii) active market wallets & secondary sales (USD). Grey dotted lines identifies explosive dynamics in the metaverse niche, according to the BSADF/PSY test.

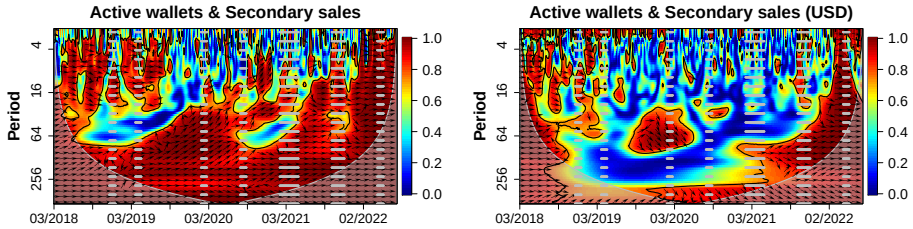
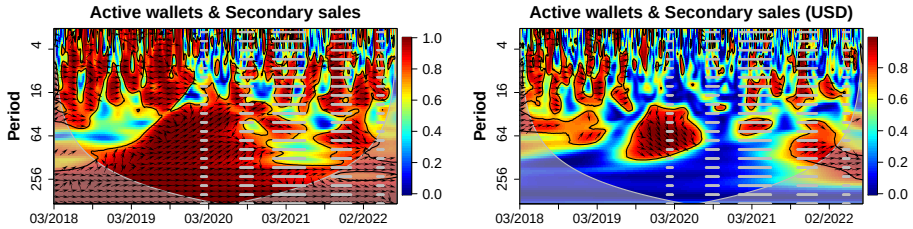


Figure. 14: Wavelet coherence between (i) active market wallets & secondary sales and (ii) active market wallets & secondary sales (USD). Grey dotted lines identifies explosive dynamics in MANA, according to the BSADF/PSY test.



References

Aharon, D. Y. and Demir, E. (2021). Nfts and asset class spillovers: Lessons from the period around the covid-19 pandemic. *Finance Research Letters*, page 102515.

Angeris, G., Kao, H.-T., Chiang, R., Noyes, C., and Chitra, T. (2021). An analysis of uniswap markets.

Aramonte, S., Huang, W., and Schrimpf, A. (2021). Defi risks and the decentralisation illusion.

Auer, R., Monnet, C., and Shin, H. S. (2021). Permissioned distributed ledgers and the governance of money. *Available at SSRN 3770075*.

Baals, L. J., Lucey, B. M., Vigne, S. A., and Long, C. (2022). Towards a research agenda on the financial economics of nft's. *Available at SSRN 4070710*.

Baker, T. (2022). How much is a vr headset? *GamesRadar*.

Bao, H. and Roubaud, D. (2022). Non-fungible token: A systematic review and research agenda. *Journal of Risk and Financial Management*, 15(5).

Baur, D. G. and Dimpfl, T. (2021). The volatility of bitcoin and its role as a medium of exchange and a store of value. *Empirical Economics*, 61(5):2663–2683.

Beer, T. (2021). Nfts of cartoon apes sell for over $24 million in sotheby's auction. *Forbes*. September 9.

Beganski, A. (2022). What is yuga labs' otherside? inside the bored ape yacht club metaverse. *DeCrypt*.

Beikverdi, A. (2015). Blizzard creates own digital currency for world of warcraft, still doesn't accept bitcoin. *Cointelegraph*.

Belaza, A. M., Ryckebusch, J., Schoors, K., Rocha, L. E., and Vandermarliere, B. (2020). On the connection between real-world circumstances and online player behaviour: The case of eve online. *PloS one*, 15(10):e0240196.

Bellavitis, C., Fisch, C., and Momtaz, P. P. (2022). The rise of decentralized autonomous organizations (daos): a first empirical glimpse. *Available at SSRN*.

Biener, V., Kalamkar, S., Nouri, N., Ofek, E., Pahud, M., Dudley, J. J., Hu, J., Kristensson, P. O., Weerasinghe, M., Pucihar, K. Č., et al. (2022). Quantifying the effects of working in vr for one week. *IEEE Transactions on Visualization and Computer Graphics*.

Bourgi, S. (2022). Blockchain games and metaverse projects raised $1.3b in q3: Dappradar. *Cointelegraph*.

Briola, A., Vidal-Tomás, D., Wang, Y., and Aste, T. (2022). Anatomy of a stablecoin's failure: The terra-luna case. *Finance Research Letters*, page 103358.

Brown, A. (2020). Travis scott has become corporate america's brand whisperer. *Forbes*.

Bruun, A. and Stentoft, M. L. (2019). Lifelogging in the wild: Participant experiences of using lifelogging as a research tool. In *IFIP Conference on Human-Computer Interaction*, pages 431–451. Springer.

Byrnes, R., Bidelski, M., Farkova, G., Lynch, H., Najem, S., Robeznieks, H., Sah, S., Sathiyanathan, A., Schmittlein, G., and Viglino, M. (2022). Technology vision 2022: Meet me in the metaverse. resreport, Accenture.

Cai, W., Wang, Z., Ernst, J. B., Hong, Z., Feng, C., and Leung, V. C. (2018). Decentralized applications: The blockchain-empowered software system. *IEEE Access*, 6:53019–53033.

Capoot, A. (2022). Meta documents show main metaverse is losing users and falling short of goals, report says. *CNBC*.

Castronova, E. (2001). Virtual worlds: A first-hand account of market and society on the cyberian frontier. *Available at SSRN 294828*.

Cazelles, B., Chavez, M., Berteaux, D., Ménard, F., Vik, J. O., Jenouvrier, S., and Stenseth, N. C. (2008). Wavelet analysis of ecological time series. *Oecologia*, 156(2):287–304.

CCi30 (2022). Data from Cryptocurrencies Index 30, https://cci30.com/.

CEU, Analysis and Research Team (2022). Metaverse - virtual world, real challenges. Technical report, Council of the European Union.

CG (2022). Data from CoinGecko, http://coingecko.com/.

Chalmers, D., Fisch, C., Matthews, R., Quinn, W., and Recker, J. (2022). Beyond the bubble: Will nfts and digital proof of ownership empower creative industry entrepreneurs? *Journal of Business Venturing Insights*, 17:e00309.

Chayka, K. (2021). Facebook wants us to live in the metaverse. *The New Yorker*.

Cheng, R., Wu, N., Chen, S., and Han, B. (2022). Will metaverse be nextg internet? vision, hype, and reality. *arXiv preprint arXiv:2201.12894*.

Coda Labs (2022). The global web3 gamer study. *Coda Labs*. https://codaplatform.com/web3-user-study/.

Corbet, S., Lucey, B., Urquhart, A., and Yarovaya, L. (2019). Cryptocurrencies as a financial asset: A systematic analysis. *International Review of Financial Analysis*, 62:182–199.

Cornell Chronicle (2007). Students get a 'second life' in first 'metanomics' course. *Cornell University*.

Dalton, J. and Gillham, J. (2022). Seeing isbelieving: How virtual reality and augmented realityare transforming business and the economy. resreport, PwC.

Daubechies, I. (1990). The wavelet transform, time-frequency localization and signal analysis. *IEEE transactions on information theory*, 36(5):961–1005.

Davidson, P. (1972). Money and the real world. *The Economic Journal*, 82(325):101–115.

Dixon, S. (2021). Global market capitalization of metaverse, facebook and gaming 2021. *Statista*.

Dowling, M. (2021a). Fertile land: Pricing non-fungible tokens. *Finance Research Letters*, page 102096.

Dowling, M. (2021b). Is non-fungible token pricing driven by cryptocurrencies? *Finance Research Letters*, page 102097.

Duan, H., Li, J., Fan, S., Lin, Z., Wu, X., and Cai, W. (2021). Metaverse for social good: A university campus prototype. In *Proceedings of the 29th ACM International Conference on Multimedia*, pages 153–161.

El Economista (2022). El gobierno destinará hasta 3,8 millones en ayudas al metaverso. *ElEconomicsta.es*.

Eng, J. (2022). Remember second life? it's now taking on big tech's metaverse. *Wall Street Journal*.

Engle, R. (2004). Risk and volatility: Econometric models and financial practice. *American economic review*, 94(3):405–420.

European Central Bank (2012). virtual currency schemes. Technical report, European Central Bank.

Gençay, R., Selçuk, F., and Whitcher, B. J. (2001). *An introduction to wavelets and other filtering methods in finance and economics*. Elsevier.

Goldberg, M., Kugler, P., and Schär, F. (2021). Land valuation in the metaverse: Location matters. *Available at SSRN*.

Heath, A. (2022). Meta's social vr platform horizon hits 300,000 users. *The Verge*.

Hoefman, K., Bramson, A., Schoors, K., and Ryckebusch, J. (2018). The impact of functional and social value on the price of goods. *Plos one*, 13(11):e0207075.

Howcroft, E. (2021). Virtual real estate plot sells for record $2.4 million. *Reuters*. November 24.

Howcroft, E. (2022). Nfts worth $100 million stolen in past year, elliptic says. *Reuters*.

Huigsloot, L. (2022). Web3 gaming still a long way from mainstream adoption: Survey. *Cointelegraph*.

Isaac, M. (2021). Facebook renames itself meta. *The New York Times*. October 28.

Jones, C. (2022). The metaverse is the future — but are current platforms failing users? *Cointelegraph*.

Kanterman, M. and Naidu, N. (2022). Metaverse may be $800 billion market, next tech platform. *Bloomberg*.

Kim, J. (2021). Advertising in the metaverse: Research agenda. *Journal of Interactive Advertising*, 21(3):141–144.

Kindig, B. (2022). The key to unlocking the metaverse is nvidia's omniverse. *Forbes*.

Koduri, R. (2021). Powering the metaverse. *Intel Newsroom*.

Koopman, S. J., Jungbacker, B., and Hol, E. (2005). Forecasting daily variability of the s&p 100 stock index using historical, realised and implied volatility measurements. *Journal of Empirical Finance*, 12(3):445–475.

Lee, L.-H., Braud, T., Zhou, P., Wang, L., Xu, D., Lin, Z., Kumar, A., Bermejo, C., and Hui, P. (2021). All one needs to know about metaverse: A complete survey on technological singularity, virtual ecosystem, and research agenda. *arXiv preprint arXiv:2110.05352*.

Leonhardt, M. (2022). Accenture designed its own metaverse for employees, complete with exact replicas of offices. *Forbes*.

Li, R., Song, T., Mei, B., Li, H., Cheng, X., and Sun, L. (2018). Blockchain for large-scale internet of things data storage and protection. *IEEE Transactions on Services Computing*, 12(5):762–771.

Ludlow, P. and Wallace, M. (2007). The virtual tabloid that witnessed the dawn of the metaverse. *Londres: Cambrigde Massachusetts*.

Lyandres, E., Palazzo, B., and Rabetti, D. (2022). Initial coin offering (ico) success and post-ico performance. *Management Science*.

Manahov, V. (2020). Cryptocurrency liquidity during extreme price movements: is there a problem with virtual money? *Quantitative Finance*, pages 1–20.

Maouchi, Y., Charfeddine, L., and El Montasser, G. (2021). Understanding digital bubbles amidst the covid-19 pandemic: Evidence from defi and nfts. *Finance Research Letters*, page 102584.

Marr, B. (2022). Will smart glasses replace smartphones in the metaverse? *Forbes*.

Mason, B. (2022). Warner music group to go metaverse with sandbox music theme park. *Yahoo Finance*. 28 January.

Mendis, D. (2021). When you buy an nft, you don't completely own it – here's why. *The Conversation*.

Meta (2014). Facebook to acquire oculus. *Meta news*.

Meta (2019). Introducing 'facebook horizon,' a new social vr world, coming to oculus quest and the rift platform in 2020. *Meta news*.

Momtaz, P. P. (2021a). Ceo emotions and firm valuation in initial coin offerings: an artificial emotional intelligence approach. *Strategic Management Journal*, 42(3):558–578.

Momtaz, P. P. (2021b). The pricing and performance of cryptocurrency. *European Journal of Finance*, 27(4-5):367–380.

Momtaz, P. P. (2022). Some very simple economics of web3 and the metaverse. *Available at SSRN*.

Moy, C. and Gadgil, A. (2022). Opportunitiesin the metaverse: How businesses can explore the metaverseand navigate the hype vs. reality. resreport, JP Morgan.

Muchmore, M. (2022). What is microsoft's metaverse strategy? *Pcmag*.

Mystakidis, S. (2022). Metaverse. *Encyclopedia*, 2(1):486–497.

Nadini, M., Alessandretti, L., Di Giacinto, F., Martino, M., Aiello, L. M., and Baronchelli, A. (2021). Mapping the nft revolution: market trends, trade networks and visual features. *arXiv preprint arXiv:2106.00647*.

Nguyen, J. K. (2022). Racial discrimination in non-fungible token (nft) prices? cryptopunk sales and skin tone. *Economics Letters*, 218:110727.

Nonfungible (2022). Shelly. *Nonfungible.com*. https://nonfungible.com/market-tracker/axieinfinity/AXIE/2965.

Nunley, C. (2021). People in the philippines are earning cryptocurrency during the pandemic by playing a video game. *CNBC*.

Nystrom, M. (2022). Gamefi monetization: A framework for redefining play-to-earn. *Messari*.

Oculus (2022). Meta quest 2 pricing changes, 'beat saber' included for a limited time. *Oculus blog*.

Olivan, J. (2022). Investing in people and infrastructure to support innovation in spain. *Meta report*.

Olson, P. (2022). Remember second life? that could be facebook's future. *The Washington Post*.

Parloff, R. (2005). From megs to riches. *Fortune*.

Patrizio, A. (2001). Virtual baggage, real bucks. *Wired*.

Patton, A. J. (2011). Volatility forecast comparison using imperfect volatility proxies. *Journal of Econometrics*, 160(1):246–256.

Pellas, N., Mystakidis, S., and Kazanidis, I. (2021). Immersive virtual reality in k-12 and higher education: A systematic review of the last decade scientific literature. *Virtual Reality*, 25(3):835–861.

Phillips, P. C. and Shi, S. (2020). Real time monitoring of asset markets: Bubbles and crises. In *Handbook of statistics*, volume 42, pages 61–80. Elsevier.

Phillips, P. C., Shi, S., and Yu, J. (2015). Testing for multiple bubbles: Historical episodes of exuberance and collapse in the s&p 500. *International economic review*, 56(4):1043–1078.

Prosegur Research (2022). Lights and shadowsof the metaverse. Technical report, Prosegur.

Qin, R., Li, J., Zhu, J., Yuan, Y., Wang, X., and Wang, F. (2021). Nft: Blockchain-based non-fungible token and applications. *Chin. J. Intell. Sci. Technol.*, 3(2):110–118.

Reback, S. (2021). Axie infinity plot sells for $2.5m. *Yahoo Finance*. November 26.

Reuters (2006). Reuters opens virtual news bureau in 'second life'. *Reuters*.

Reynolds, S. (2022). Metaverse majors struggle as user base falls short of market expectations. *Coindesk*.

Rua, A. and Nunes, L. C. (2009). International comovement of stock market returns: A wavelet analysis. *Journal of Empirical Finance*, 16(4):632–639.

Shimron, L. (2022). The australian open swings into the metaverse, will it be an ace? *Forbes*. 12 January.

Somraaj, S. (2022). Tether loses dollar peg amid ongoing stablecoin crisis. *Decrypt*.

Statista (2022). Number of monthly active users (mau) of blizzard entertainment worldwide from 1st quarter 2018 to 2nd quarter 2022. *Statista.com*.

Stephenson, N. (1992). *Snow crash: A novel*. Spectra.

Stern, J. (2022). Trapped in the metaverse: Here's what 24 hours in vr feels like. *Wall Street Journal*.

Stokel-Walker, C. (2013). Second life's strange second life. *The Verge*.

Torrence, C. and Compo, G. P. (1998). A practical guide to wavelet analysis. *Bulletin of the American Meteorological society*, 79(1):61–78.

Turiel, J. D. and Aste, T. (2022). Heterogeneous criticality in high frequency finance: a phase transition in flash crashes. *Entropy*, 24(2):257.

Valdes-Dapena, P. (2006). Real cars drive into second life. *CNN*.

Vallance, C. (2021). Facebook's metamorphosis - will it work? *BBC*.

Vidal-Tomás, D. (2021). The entry and exit dynamics of the cryptocurrency market. *Res. Int. Bus. Finance.*, 58:101504.

Vidal-Tomás, D. (2022a). The new crypto niche: Nfts, play-to-earn, and metaverse tokens. *Finance Research Letters*, page 102742.

Vidal-Tomás, D. (2022b). Which cryptocurrency data sources should scholars use? *International Review of Financial Analysis*, 81:102061.

Walras, L. (2013). *Elements of pure economics*. Routledge.

Wang, Q., Li, R., Wang, Q., and Chen, S. (2021). Non-fungible token (nft): Overview, evaluation, opportunities and challenges. *arXiv preprint arXiv:2105.07447*.

Wei, W. C. (2018). Liquidity and market efficiency in cryptocurrencies. *Economics Letters*, 168:21–24.

White, L. (2022). Hsbc buys virtual plot of land in digital push. *Reuters*. 17 March.

White, L. H. (1984). Competitive payments systems and the unit of account. *The American Economic Review*, 74(4):699–712.

Wood, R. (2021). This oculus vr headset could feature lifelike resolution – here's why that matters. *TechRadar*.

Xu, D., Li, Y., Chen, X., Li, J., Hui, P., Chen, S., and Crowcroft, J. (2018). A survey of opportunistic offloading. *IEEE Communications Surveys & Tutorials*, 20(3):2198–2236.

Yang, Q., Zhao, Y., Huang, H., Xiong, Z., Kang, J., and Zheng, Z. (2022). Fusing blockchain and ai with metaverse: A survey. *IEEE Open Journal of the Computer Society*, 3:122–136.

Yermack, D. (2015). Is bitcoin a real currency? an economic appraisal. In *Handbook of digital currency*, pages 31–43. Elsevier.

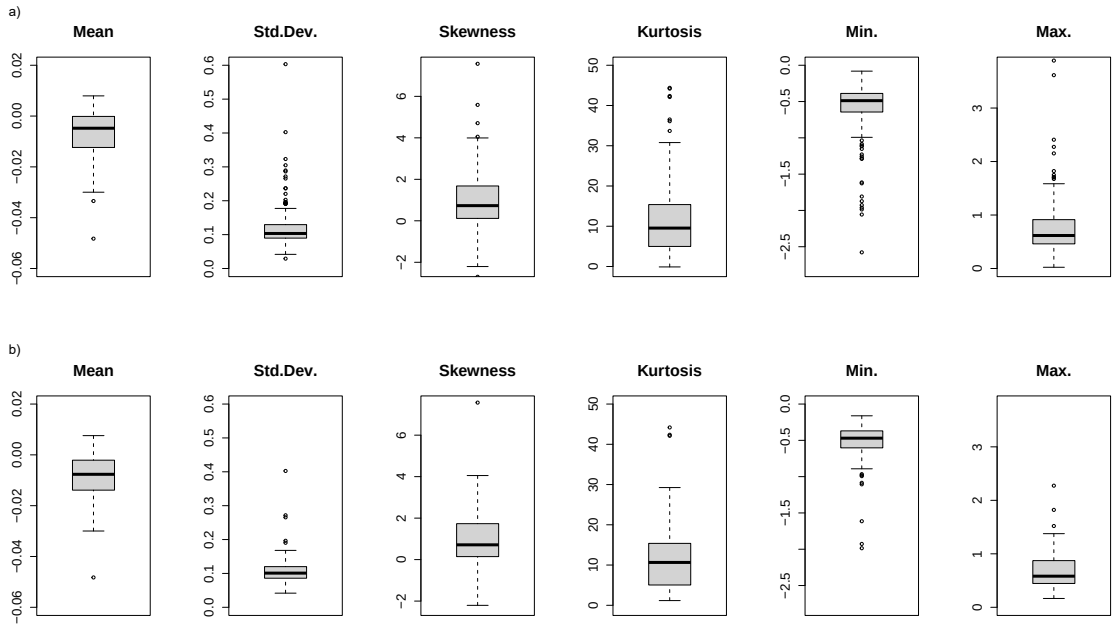
Zyskind, G., Nathan, O., et al. (2015). Decentralizing privacy: Using blockchain to protect personal data. In *2015 IEEE Security and Privacy Workshops*, pages 180–184. IEEE.

Supplement to:

"The illusion of the metaverse and meta-economy"

1 Descriptive statistics of daily log-returns

Figure. 1: Descriptive statistics of daily log-returns: a) metaverse, b) metaverse & play-to-earn.



2 Descriptive statistics of the NFT features

Table 1: Descriptive statistics of NFT features in the metaverse industry.

NFT features	Sample period	Observations	Mean	Std.Dev.	Skewness	Kurtosis	Min.	Max.
Number of sales	19/03/2018 - 01/08/2022	1597	327.68	1886.60	31.67	1139.86	1.00	69613.00
Sales (USD)	19/03/2018 - 01/08/2022	1597	1533338.40	17386077.68	34.30	1265.24	3.44	656326295.99
Average (USD)	19/03/2018 - 01/08/2022	1597	2318.91	3453.26	2.64	8.23	0.86	27063.33
Active market wallets	19/03/2018 - 01/08/2022	1597	223.21	1011.46	31.15	1118.95	2.00	37202.00
Primary sales	19/03/2018 - 01/08/2022	1597	176.73	1534.69	30.90	1088.75	0.00	55849.00
Secondary sales	19/03/2018 - 01/08/2022	1597	150.95	443.78	20.97	588.86	1.00	13764.00
Primary sales (USD)	19/03/2018 - 01/08/2022	1597	428535.48	9066458.72	39.24	1554.87	0.00	360504272.82
Secondary sales (USD)	19/03/2018 - 01/08/2022	1597	1104802.92	8904276.43	26.92	821.12	0.21	295822023.18

Table 2: Descriptive statistics of the NFT features in Decentraland.

NFT features	Sample period	Observations	Mean	Std.Dev.	Skewness	Kurtosis	Min.	Max.
Number of sales	19/03/2018 - 01/08/2022	1597	67.12	220.41	10.23	132.98	0.00	4005.00
Sales (USD)	19/03/2018 - 01/08/2022	1597	134518.18	332663.80	5.54	42.38	0.00	4285220.02
Average (USD)	19/03/2018 - 01/08/2022	1597	2883.30	4866.53	4.48	30.09	0.00	56694.16
Active market wallets	19/03/2018 - 01/08/2022	1597	41.30	64.64	9.88	153.93	0.00	1406.00
Primary sales	19/03/2018 - 01/08/2022	1597	37.31	178.35	13.42	230.91	0.00	3963.00
Secondary sales	19/03/2018 - 01/08/2022	1597	29.81	77.20	10.12	123.24	0.00	1213.00
Primary sales (USD)	19/03/2018 - 01/08/2022	1597	29102.76	133816.93	11.58	181.60	0.00	2701053.54
Secondary sales (USD)	19/03/2018 - 01/08/2022	1597	105415.41	260883.80	5.51	40.50	0.00	3093692.80

Table 3: Descriptive statistics of the NFT features in The Sandbox.

NFT features	Sample period	Observations	Mean	Std.Dev.	Skewness	Kurtosis	Min.	Max.
Number of sales	02/12/2019 - 01/08/2022	717	165.28	594.89	18.64	409.69	0.00	13947.00
Sales (USD)	02/12/2019 - 01/08/2022	717	676692.16	1546493.80	4.35	24.30	0.00	15664035.29
Average (USD)	02/12/2019 - 01/08/2022	717	3762.24	4642.22	1.41	0.69	0.00	17772.55
Active market wallets	02/12/2019 - 01/08/2022	717	102.77	137.05	3.10	10.61	0.00	901.00
Primary sales	02/12/2019 - 01/08/2022	717	60.71	576.54	19.98	451.36	0.00	13747.00
Secondary sales	02/12/2019 - 01/08/2022	717	104.57	112.13	2.91	10.61	0.00	878.00
Primary sales (USD)	02/12/2019 - 01/08/2022	717	77919.08	345128.90	7.06	60.19	0.00	4327963.44
Secondary sales (USD)	02/12/2019 - 01/08/2022	717	598773.09	1432319.25	4.57	26.57	0.00	14685303.61

3 Evolution of the NFT features without log-transformation

Figure. 2: Evolution of the NFT features in the metaverse industry.

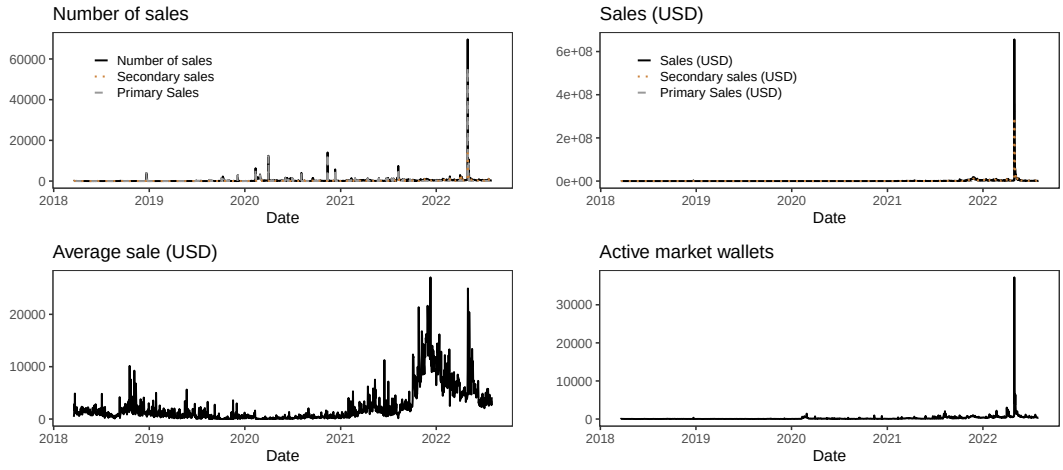


Figure. 3: Evolution of the NFT features in Decentraland.

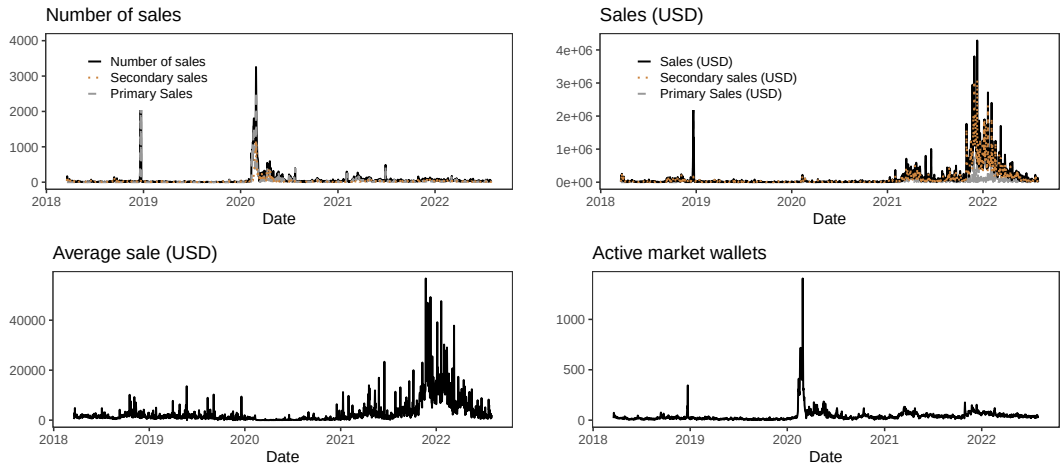
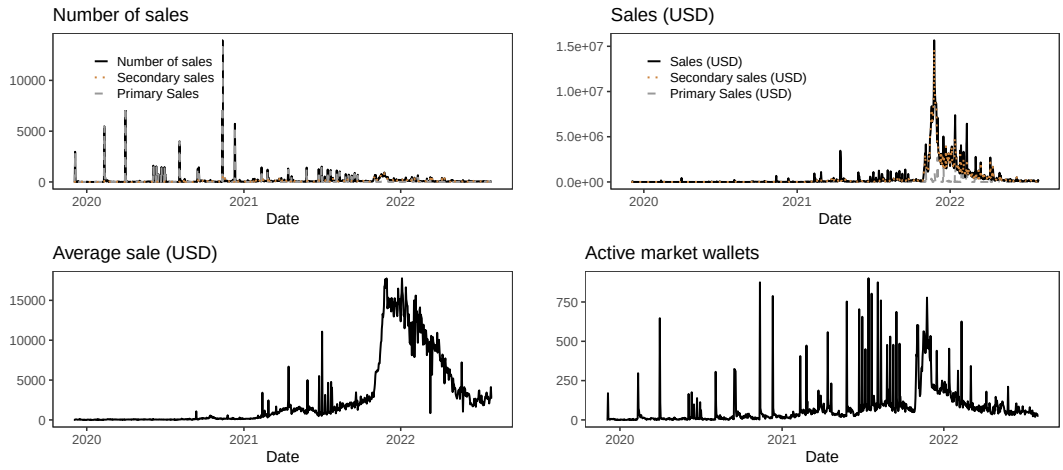
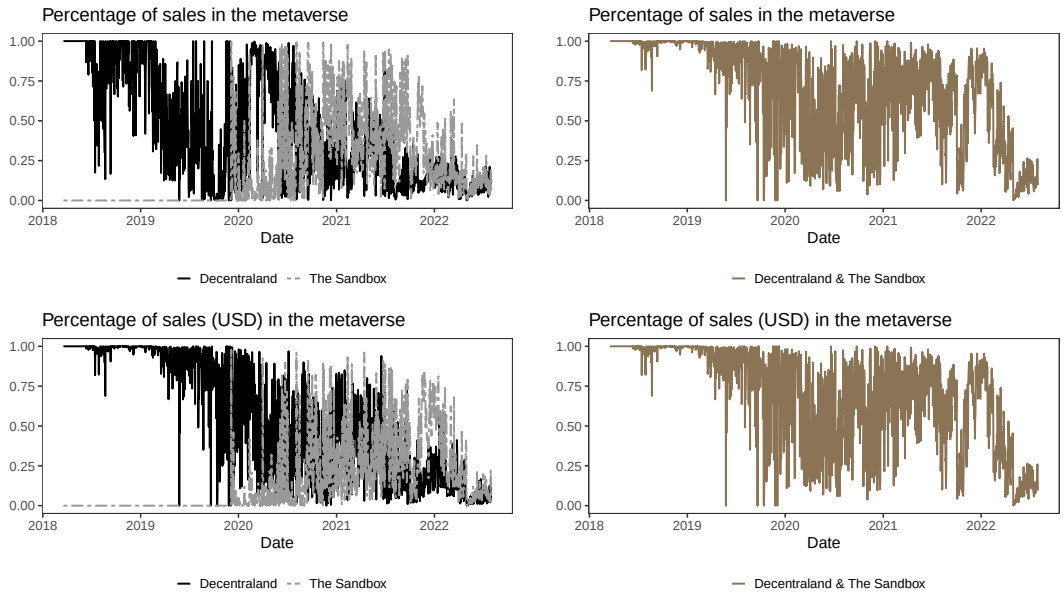


Figure. 4: Evolution of the NFT features in The Sandbox.



4 Percentage of sales related to Decentraland and The Sandbox in the metaverse

Figure. 5: Percentage of sales related to Decentraland and The Sandbox in the metaverse.



5 Histograms: buy-and-hold (abnormal) returns (BHR & BHAR)

Figure. 6: Histogram of buy-and-hold (abnormal) returns (BHR & BHAR) for metaverse tokens.

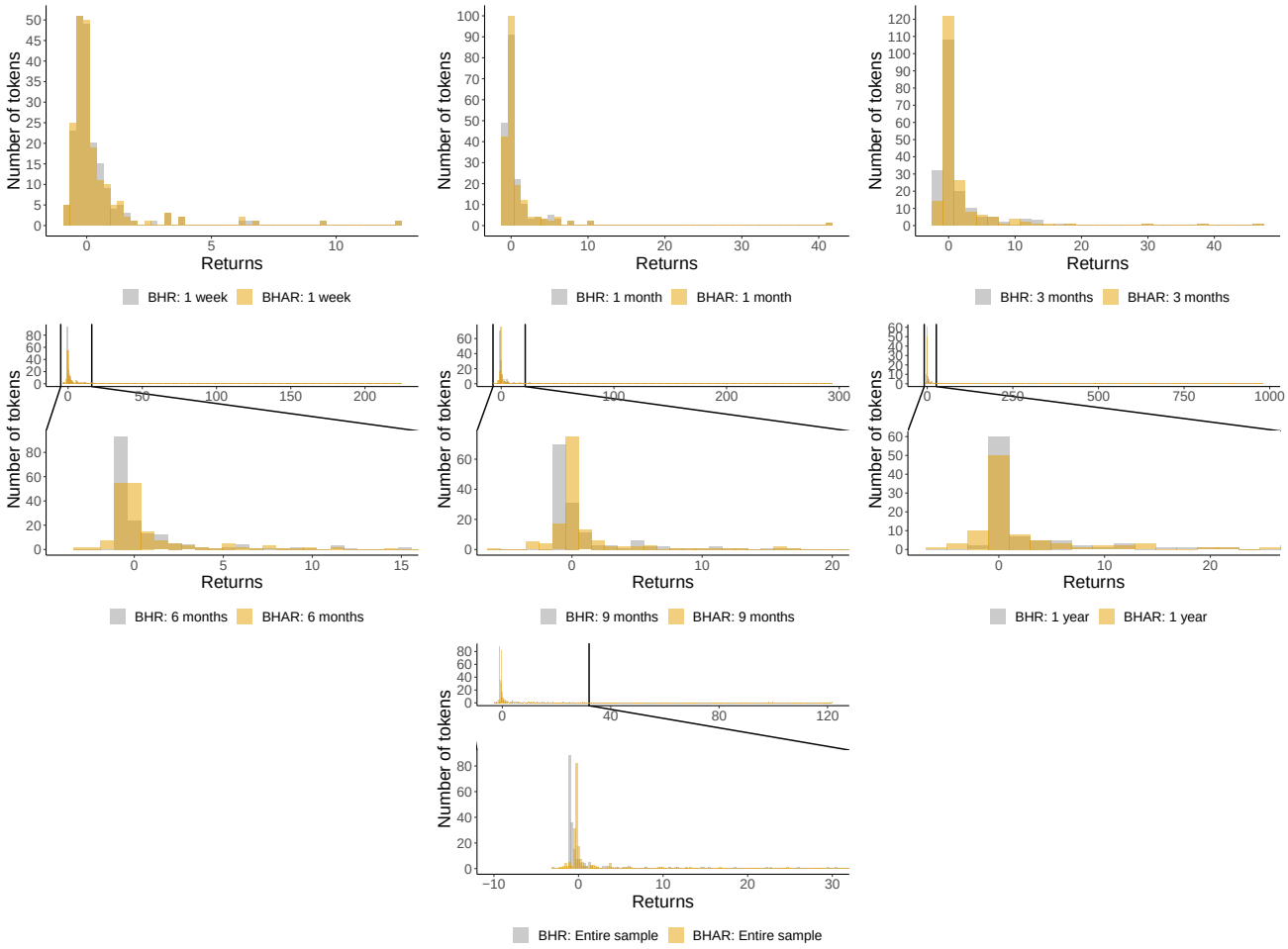
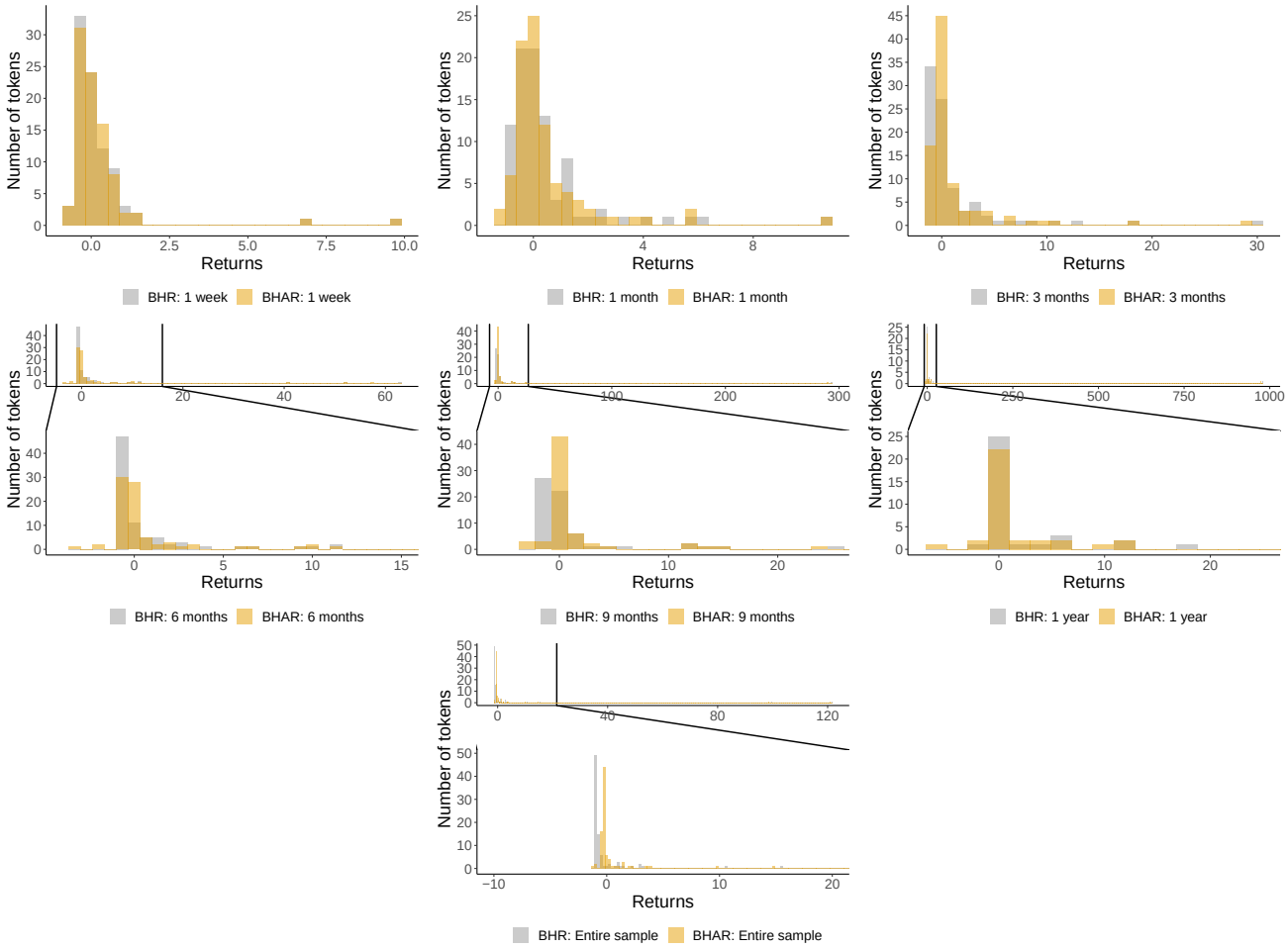


Figure. 7: Histogram of buy-and-hold (abnormal) returns (BHR & BHAR) for metaverse & play-to-earn tokens.



6 Wavelet coherence analysis

Figure. 8: Wavelet coherence between MANA returns and growth rates of NFT features from the Decentraland marketplace. Grey dotted lines identifies explosive dynamics in MANA, according to the BSADF/PSY test.

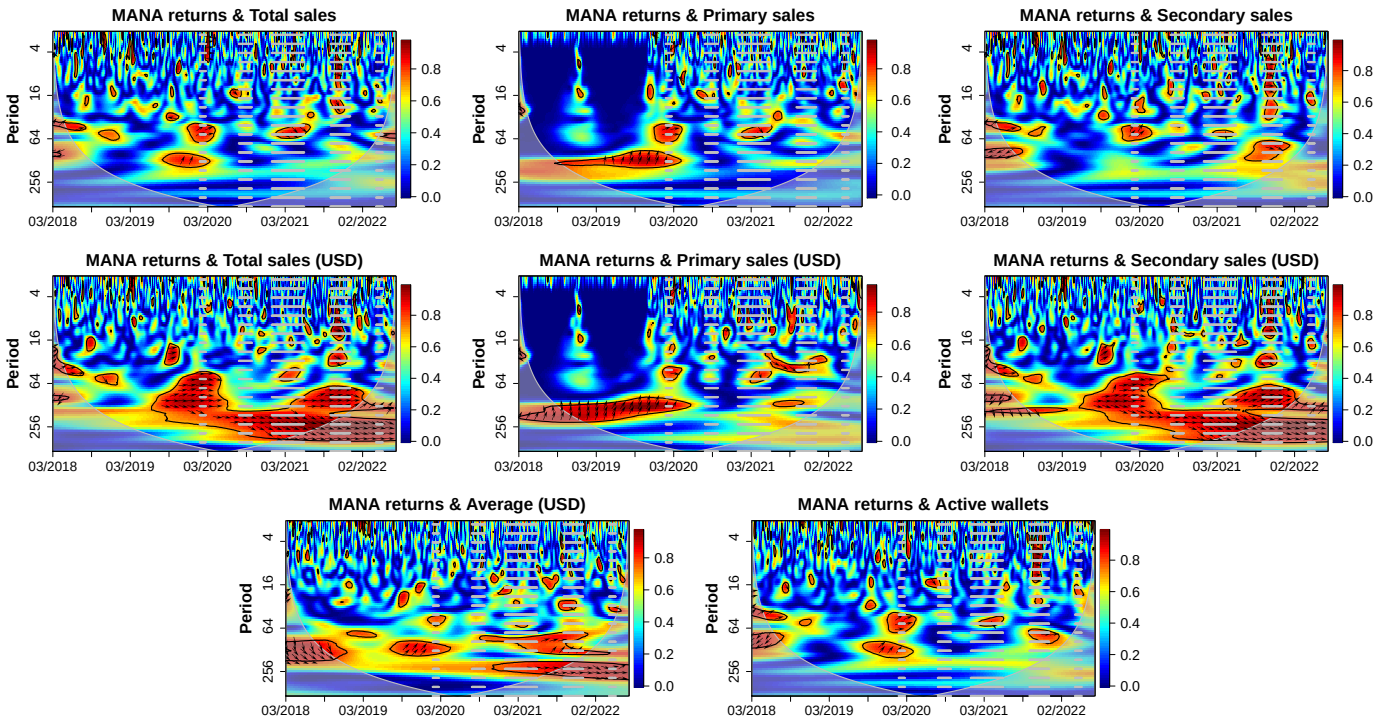
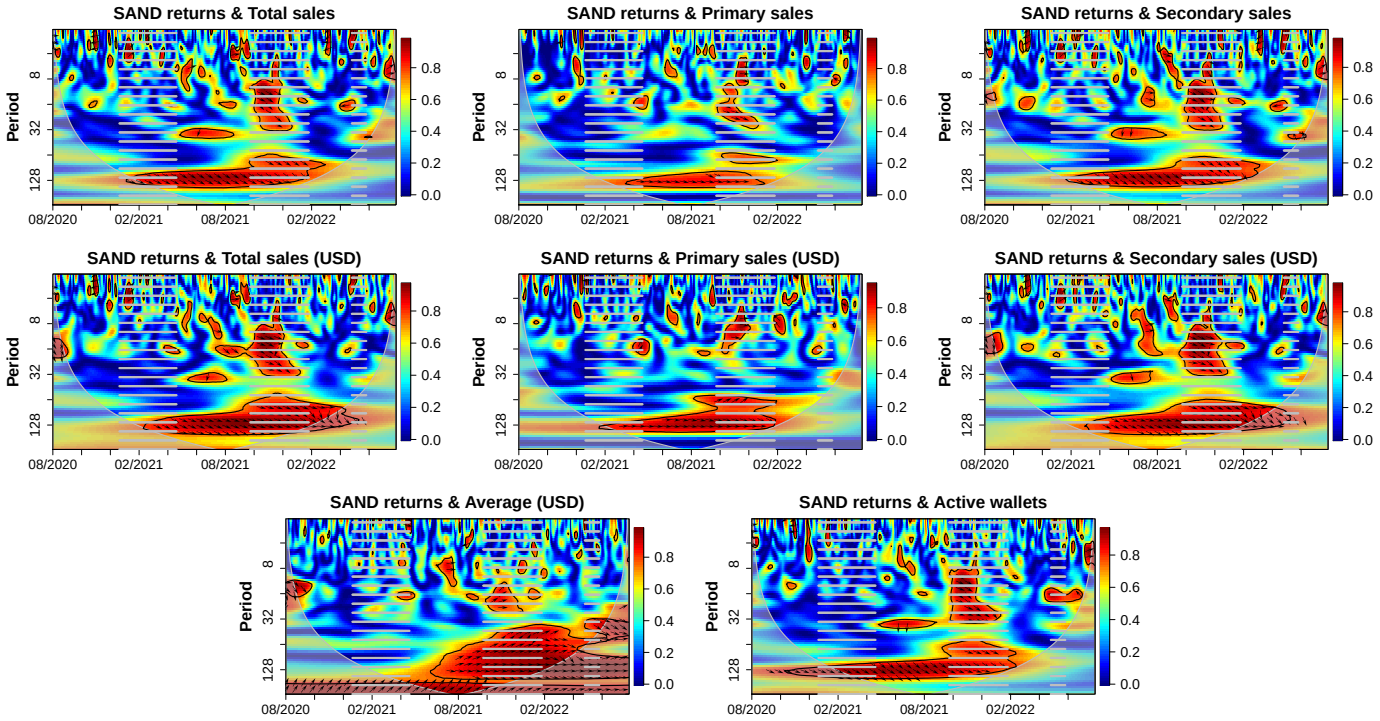
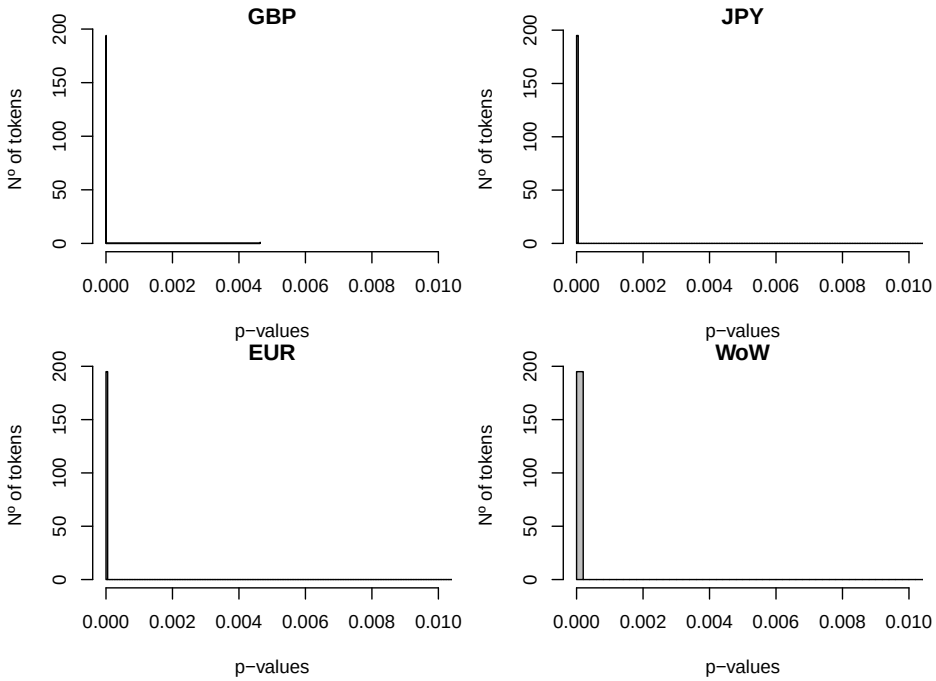


Figure. 9: Wavelet coherence between SAND returns and growth rates of NFT features from the The Sandbox marketplace. Grey dotted lines identifies explosive dynamics in SAND, according to the BSADF/PSY test.



7 P-values reported by the Wilcoxon test.

Figure. 10: P-values reported by the Wilcoxon test.



8 Otherside & Apecoin

Figure. 11: Percentage of sales related to Decentraland, The Sandbox and Otherside in the metaverse.

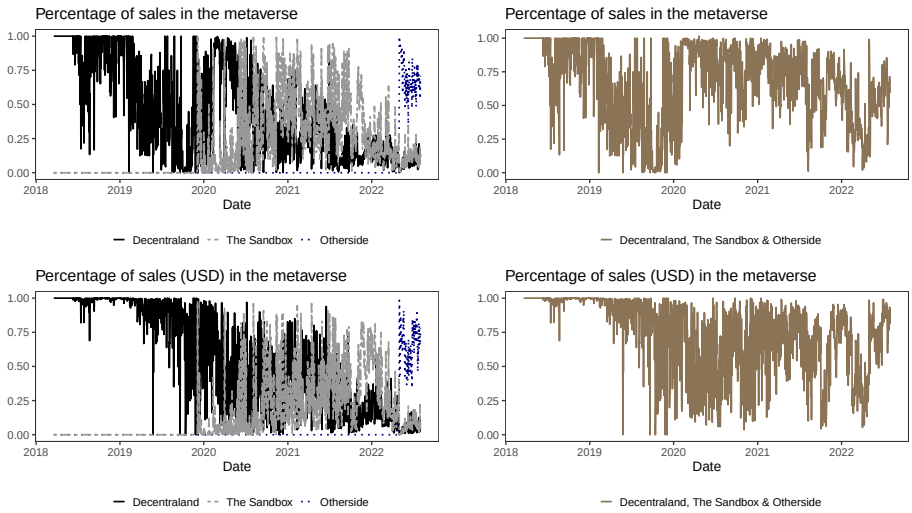


Figure. 12: APE prices (black line) and bubbles detected by the BSADF/PSY test considering the 90% critical value (grey areas).