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Abstract

The combination of blockchain technologies and the gaming industry has given rise to metaverses and play-to-earn games, which incorporate their own economy, commerce, and currencies, namely, metaverse and play-to-earn tokens. In this study, we analysed the performance and dynamics of 174 tokens, showing that this new crypto niche is characterised by (i) a positive performance in the long run, (ii) the absence of high co-movements with the cryptocurrency market, (iii) the emergence of bubbles, (iv) and the absence of high correlations with NFT features, such as number of transactions, sales and Google searches.

JEL codes: G10 · G11 · G40

Keywords: Metaverse · Play-to-earn · NFT · Cryptocurrency · COVID-19 · Diversification ·

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1. Introduction

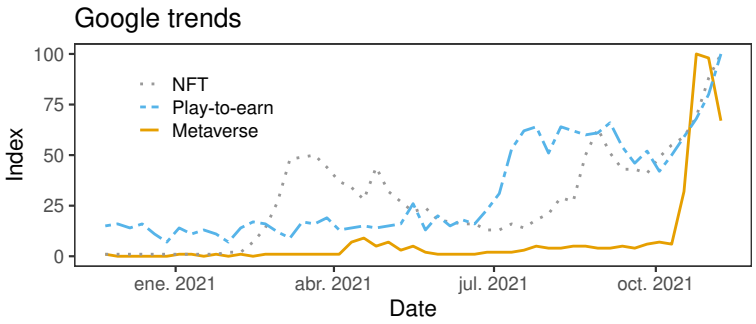
Non-fungible tokens (NFTs) have become the new centre of attention for both industrial and scientific communities in the cryptocurrency market. This trend happens because of their technical properties and their profitable transactions, as can be observed with the set of 101 NFTs from the "Bored Ape Yacht Club" collection, which was sold for $24.4 million (Beer, 2021). Unlike traditional cryptocurrencies (e.g. Bitcoin or Ethereum), which coins are all equivalent, indistinguishable, and "fungible", NFTs are defined as pure digital assets that cannot be exchanged like-for-like. Consequently, NFTs are unique and "non-fungible" (Wang et al., 2021). This intrinsic feature allows NFTs to demonstrate the authenticity and ownership of different items in distinct fields, which explains its fast expansion on virtual events, digital collectibles (e.g. trading cards, digital images, videos, virtual real estate, domain names, and crypto stamps), play-to-earn games, and metaverses [see Wang et al., 2021 and Nadini et al., 2021]. Indeed, it has been in the metaverse and play-to-earn games where investors and gamers have flocked in recent months and, consequently, virtual property sales and token prices are setting new records. As proofs of it, 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), respectively. Additionally, their corresponding digital currencies, MANA and AXS, have been found among the 40 largest cryptocurrencies by market capitalisation due to their increase in price (Ledesma, 2021).

Interest in the gaming industry and its NFT applications is observed in NFT transaction numbers and in the attention of investors, as we report with the evolution of Google searches in Fig. (1). Consequently, given the increasing awareness in this niche, we shed more light on play-to-earn games and metaverses. On the one hand, play-to-earn games are based on a business model in which users play a blockchain game and earn rewards while doing it. The critical element of these games is that users mainly obtain two types of in-game assets as rewards: (i) NFT items with variable scarcity and (ii) a particular type of cryptocurrency or play-to-earn token. Whereas NFTs (e.g. weapons, skins, and monsters) can be purchased and sold on the open market (e.g. OpenSea), game developers create the cryptocurrency or play-to-earn token, which has an inherent currency value and can be traded by players during the in-game experience.[1]

On the other hand, a metaverse is defined as an immersive and shared virtual world in which different activities are allowed for its users, which are represented by avatars. One of its main features is economic governance and metaverse commerce, since this virtual world has its own economy and currencies with which users can trade any item (Lee et al., 2021). Specifically, a crypto metaverse is a metaverse in which blockchain is incorporated into its underlying technology and economy (e.g. metaverse tokens). Interestingly, as Wang et al. (2021) stated, metaverses can include all available NFT applications. As a consequence, its ecosystem could also include play-to-earn games and marketplaces to trade assets or virtual properties (e.g. land parcels and arts).[2]

[1] Some examples are Splinterlands, Axie Infinity and Alien worlds.
[2] The best examples in this case are Decentraland and Sandbox.

Figure. 1: Worldwide Google searches for "NFT", "play-to-earn" and "metaverse". The maximum popularity during the analysed period is indicated by an index equal to 100.

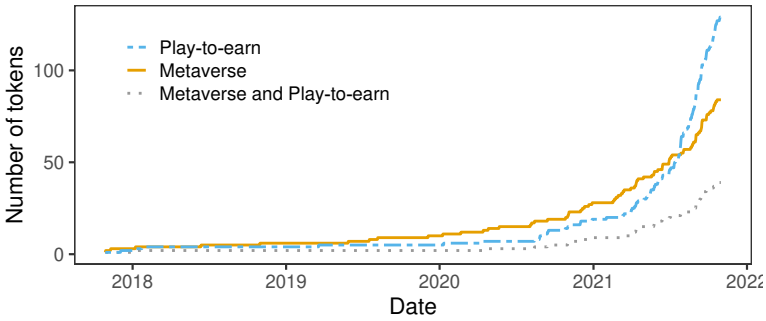


Some light on NFTs and the gaming industry has been shed by recent studies. Dowling (2021a) analysed the pricing of parcels of virtual real estate in Decentraland, showing that the price series of these NFTs are characterised by inefficiency and a rise in value. In a follow-up study, Dowling (2021b) demonstrated the existence of limited volatility transmission effects between NFT pricing (Decentraland, Cryptopunks and Axie Infinity) and cryptocurrencies (Bitcoin and Ethereum). Nadini et al. (2021) analysed data related to 6.1 million trades of 4.7 million NFTs, distinguishing between art, collectables, games, metaverse and utility categories. Since July 2020, it has been shown in their results that the most exchanged NFTs belong to the gaming industry. Further, traders seem to be specialised, performing at least 73% of their transactions in a specific NFT category. From a more general perspective, Aharon and Demir (2021) analysed the connectedness between the entire NFT market and other financial assets (e.g. equities, bonds, currencies, gold, oil and Ethereum) using the TVP-VAR approach. They have shown in their main results that NFTs are shock independent from standard asset classes. Moreover, NFTs seem to have diversification benefits during turbulent times. Unlike these papers, we did not focus on the properties of specific NFT trades (e.g. virtual lands, weapons, or any in-game item) but on the properties of all the existing play-to-earn and metaverse tokens, which are the cornerstone of the economy on these blockchain applications.[3] Therefore, compared to Dowling (2021a,b), Nadini et al. (2021) and Aharon and Demir (2021), we analysed the financial features of the "fungible" play-to-earn and metaverse tokens, which are used for trading and play in blockchain games and metaverses, instead of studying the properties of the "non-fungible" items from these virtual worlds.

Indeed, the increasing interest in NFTs, play-to-earn games and metaverses has given rise to a remarkable increase in initial coin offerings (ICO) focused on the gaming industry (i.e. initial game offering, IGO). This is a similar tendency observed during the ICO bubble in the entire cryptocurrency market in 2017 (Momtaz, 2021, Vidal-Tomás, 2021). Specifically, on January 1, 2020, there were five play-to-earn and 10 metaverse tokens. One year later, on January 1, 2021, the market included 19 play-to-earn and 28 metaverse tokens. Finally, when writing this article (October 31, 2021), we observed 129 play-to-earn and 84 metaverse tokens. This landscape is a demonstration of the growth of a new niche in the cryptocurrency market [see Fig. (2)].

[3]Instead of using existing cryptocurrencies, such as Ethereum (e.g. Cryptopunks), some play-to-earn games and metaverses create their own in-game/metaverse token, which can be obtained as rewards, staking, through liquidity pools, or purchasing with fiat currencies.

Figure. 2: Number of tokens over time: a) play-to-earn, b) metaverse, c) metaverse & play-to-earn.



In this study, we contribute to the cryptocurrency literature by analysing the short/long-run performance and dynamics of this new crypto niche, which is of paramount importance for investors, gamers and blockchain companies. First, traders can invest in gaming and metaverse projects without playing games, interacting in the metaverse or purchasing particular NFTs using in-game tokens. Thus, it is crucial to examine whether (i) these tokens are profitable and (ii) can be used as diversifiers for cryptocurrency portfolios. Second, from the perspective of gamers, users continuously play to obtain tokens as rewards, with the expectation of positive returns in the long run. Third, from a business approach, the positive performance of these tokens could attract more blockchain companies interested in creating new gaming and metaverse projects to this niche.

Moreover, we also analysed the emergence of financial bubbles and the co-movement between market returns and NFT features, given that the existence of bubbles and the absence of correlations between token returns and NFT properties would underline the gap between the financial and real sphere in this niche. In other words, the financial performance of metaverse and play-to-earn tokens could not be justified by the real evolution of NFT sales and investor attention.

Therefore, considering the financial interest of the different agents, we specified the following hypotheses in our study: (H1) traders and gamers obtain a positive performance in the short run with metaverse and play-to-earn tokens, (H2) traders outperform the cryptocurrency market investing in metaverse and play-to-earn tokens in the long run, (H3) traders diversify cryptocurrency portfolios, including metaverse and play-to-earn tokens, (H4) the effort of gamers in playing blockchain games to obtain tokens is compensated with positive returns, (H5) blockchain companies obtain positive returns with IGOs in the long run, (H6) blockchain companies diversify their blockchain product portfolios with metaverse and play-to-earn games that include tokens, (H7) this crypto niche is characterised by explosive price behaviour and the existence of bubbles, and (H8) play-to-earn and metaverse returns are not correlated to NFT features. We show that H1 and H2 were rejected in our results, but we cannot reject the other hypotheses.

2. Data

We used daily price series of 174 tokens from the CoinGecko database (CG, 2021) in this study. More specifically, based on CoinGecko and Coinmarketcap categories, we analysed 129 play-to-earn tokens and 84 metaverse tokens between October 28, 2017, and October 31, 2021, given that the first metaverse token, MANA from Decentraland, was introduced

on October 28, 2017.[4] We also individually analysed metaverse projects that incorporate play-to-earn games (i.e. tokens are classified in both categories), whose sub-sample includes 39 tokens. Moreover, we used the CCi30 index (CCi30, 2021) as the cryptocurrency market capitalisation-weighted benchmark from October 28, 2017, to October 31, 2021. Specifically, we employed this index because (i) it has been widely used in the cryptocurrency literature (see Manahov, 2020 and Vidal-Tomás, 2021) and (ii) we are provided with opening prices, allowing us to analyse the short-run performance of tokens. Thus, compared to other crypto indices, with the CCi30 index we can adequately examine the short/long-run performance and dynamics of play-to-earn and metaverse tokens concerning the evolution of the entire cryptocurrency market.[5,6]

For all price time series, we computed daily log returns. The descriptive statistics are shown in Table 1 and Fig. (3). For play-to-earn and metaverse tokens, we reported box plots with the entire sample of tokens in Fig. (3), showing the corresponding median in Table 1. As can be observed, the novelty of these projects is highlighted by their short life, given the low number of observations in the median: play-to-earn (89), metaverse (174) and metaverse & play-to-earn (123). Moreover, considering the mean and skewness values, the performance of these tokens is positive, on average, even though they are also characterised by high volatility and heterogeneity.[7]

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

Category (Median)	Tokens	Observations	Mean	Std.Dev.	Skewness	Kurtosis	Min.	Max.
Play-to-earn	129	89	0.0032	0.1413	0.7547	3.5159	-0.3817	0.5600
Metaverse	84	174	0.0077	0.1328	0.9211	4.4136	-0.3800	0.5778
Metaverse & Play-to-earn	39	123	0.0093	0.1329	0.9314	3.5810	-0.3185	0.5549
Crypto benchmark		Observations	Mean	Std.Dev.	Skewness	Kurtosis	Min.	Max.
CCi30		1464	0.0013	0.0476	-1.3994	11.0560	-0.4845	0.1957

Finally, to analyse the existence of bubbles in this niche and the co-movement between market returns and NFT features, we also used the data described in Table 2. Descriptive statistics are reported in Table 3, where we observed that the play-to-earn market is more developed than the metaverse market.

[4] The list of tokens used in this paper, with names and symbols, is available in the supplementary material.
[5] In the supplementary material, we included the constituents of the CCi30 index.
[6] For robustness purposes, in the supplementary material we also used the MVDA25 index, as an alternative crypto benchmark, obtaining consistent results.
[7] We reported the descriptive statistics of each token, distinguishing by category, in the supplementary material.

Figure. 3: Descriptive statistics of daily log-returns: a) play-to-earn b) metaverse, c) metaverse & play-to-earn.

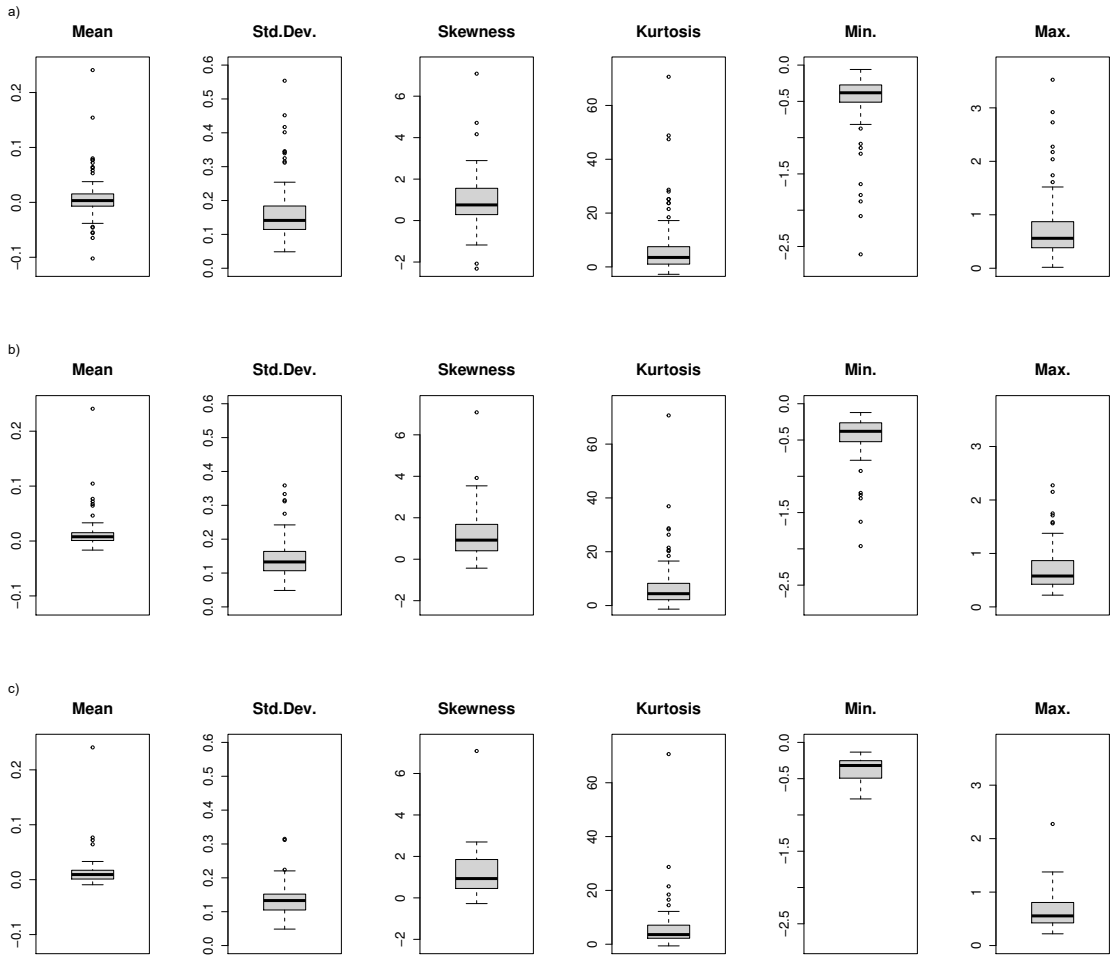


Table 2: Crypto indices of the gaming industry and NFT features used in this study.

Crypto indices	Description
MVI	The Metaverse Index (MVI) is a modified market cap-weighted index. The trend of entertainment, sports and business shifting to take place in virtual environments is tracked in this index. Thus, it includes the main metaverse and play-to-earn tokens, such as AXS, MANA, ILV and ENJ. This index was created on April 7, 2021. Source: www.indexcoop.com (MVI, 2021).
Play-to-earn/Metaverse EW market	The equally-weighted (EW) 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. We calculate $r_{t,m}$ in daily and weekly frequency.

NFT features	Description
Play-to-earn/Metaverse: Total Sales (USD)	Total USD spent on completed NFT sales for play-to earn and metaverse projects. Source: www.nonfungible.com.
Play-to-earn/Metaverse: Number of sales	The total number of NFT sales for play-to earn and metaverse projects. Source: www.nonfungible.com.
Play-to-earn/Metaverse: Google searches	Weekly index of Google Trend for the words “play-to earn” and “metaverse” scaled by 100. Source: www.trends.google.com.

Table 3: Descriptive statistics of (i) log-returns for each crypto index and (ii) NFT features.

Crypto indices	Sample period	Observations	Mean	Std.Dev.	Skewness	Kurtosis	Min.	Max.
MVI	07/04/2021 - 31/10/2021	208	0.0037	0.0804	-0.2306	3.0804	-0.3598	0.2675
Play-to-earn EW market (daily)	25/12/2017 - 31/10/2021	1407	-0.0002	0.0665	-0.9488	12.0306	-0.6644	0.3748
Play-to-earn EW market (weekly)	28/10/2017 - 31/10/2021	209	0.0143	0.2073	1.5727	10.3656	-0.6432	1.3998
Metaverse EW market (daily)	19/03/2018 - 31/10/2021	1323	0.0012	0.0564	-0.7671	6.0164	-0.4912	0.1992
Metaverse EW market (weekly)	28/10/2017 - 31/10/2021	209	0.0125	0.1769	0.6285	3.2890	-0.6025	0.7879

NFT features	Sample period	Observations	Mean	Std.Dev.	Skewness	Kurtosis	Min.	Max.
Play-to-earn: Total sales (USD)	25/12/2017 - 31/10/2021	1407	1515416.24	5886788.12	5.20	32.64	0.00	70237962.70
Play-to-earn: Number of sales	25/12/2017 - 31/10/2021	1407	7353	24874.56	4.38	18.10	0.00	156125.00
Play-to-earn: Google trends (weekly)	28/10/2017 - 31/10/2021	209	21.81	16.60	2.71	7.12	7.00	100.00
Metaverse: Total sales (USD)	19/03/2018 - 31/10/2021	1323	177843.63	493579.33	7.51	88.90	0.00	8718866.39
Metaverse: Number of sales	19/03/2018 - 31/10/2021	1323	209	688.95	12.82	215.03	0.00	14061.00
Metaverse: Google trends (weekly)	28/10/2017 - 31/10/2021	209	1.79	9.76	9.06	84.67	0.00	100.00

3. Methodology

3.1. Performance: first-day and buy-and-hold (abnormal) returns

We used the average first-day and average buy-and-hold returns to analyse the short- and long-run performance of play-to-earn and metaverse tokens. Following Momtaz (2021), the former are calculated as the sum over all tokens i of the closing and opening price difference over the opening price of the first trading day, divided by the number of tokens n in each category:

$$\overline{R} = \frac{1}{n}\sum_{i=1}^{n}\frac{P_{i,1} - P_{i,0}}{P_{i,0}}, \tag{1}$$

where $\overline{R}$ is the average first-day returns, $P_{i,1}$ denotes closing prices and $P_{i,0}$ represents opening prices.

To analyse the long-term performance we computed the average buy-and-hold returns ($\overline{BHR}$) in a similar way to Eq. (1). Nonetheless, compared to Eq. (1), we replaced $P_{i,1}$ with the closing price after the focal holding period ($P_{i,\tau}$):

$$\overline{BHR}_{\tau} = \frac{1}{n}\sum_{i=1}^{n}\frac{P_{i,\tau} - P_{i,0}}{P_{i,0}}, \tag{2}$$

where the holding period is denoted by 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 periods at our disposal.

We calculated first-day abnormal returns and buy-and-hold abnormal returns by adjusting $\overline{R}$ and $\overline{BHR}_{\tau}$ with a market capitalisation-weighted benchmark to examine the performance of these tokens compared to the entire cryptocurrency market. In other words, average first-day abnormal returns ($\overline{AR}$) and average buy-and-hold abnormal returns ($\overline{BHAR}_{\tau}$) are defined as $\overline{R}$ and $\overline{BHR}_{\tau}$ less the market return, which is represented by the CCi30 market capitalisation index:

$$\overline{AR} = \frac{1}{n}\sum_{i=1}^{n}\left[\frac{P_{i,1} - P_{i,0}}{P_{i,0}} - \frac{P_{CCi30,1} - P_{CCi30,0}}{P_{CCi30,0}}\right], \tag{3}$$

$$\overline{BHAR}_{\tau} = \frac{1}{n}\sum_{i=1}^{n}\left[\frac{P_{i,\tau} - P_{i,0}}{P_{i,0}} - \frac{P_{CCi30,\tau} - P_{CCi30,0}}{P_{CCi30,0}}\right], \tag{4}$$

where $P_{CCi30,0}$ is the same day as $P_{i,0}$.

3.2. Dynamics: Pearson and Kendall correlations

We computed the Pearson correlation, which is the most common measure for studying the similarity between the dynamics of assets, to analyse the co-movement between the cryptocurrency market (CCi30) and play-to-earn/metaverse tokens. We also computed the Kendall correlation (Kendall, 1938), as it is appropriate for time series that are short and non-normal (Aste, 2019), a generalised characteristic of our dataset, given the novelty of these assets. Indeed, given the short sample period of some tokens, we analysed only tokens with more than 30 observations to obtain reliable results.

3.3. Financial bubble: Backward Sup Augmented Dickey-Fuller test (BSADF)

We used the methodology proposed by Phillips et al. (2015), the Backward Sup Augmented Dickey-Fuller test (BSADF), to analyse the existence of bubbles in this crypto niche. With this method, it is possible to identify explosive price behaviour in financial markets (see, Enoksen et al., 2020 and Corbet et al., 2018) through sup ADF tests applied on a backward expanding sample sequence. Phillips et al. (2015) defined the origination/termination date of a bubble as the first observation whose backward sup ADF statistic exceeded/fell below the critical value.

3.4. Market returns and NFT features: Wavelet coherence approach

Following Dowling (2021b), we shed some light on the connections between NFT features and token returns 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 [see Torrence and Compo (1998) for a detailed description of the methodology]. 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 (low coherence/co-movement) to red (high coherence/co-movement). Finally, 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. In this subsection, we represented the evolution of all the metaverse and play-to-earn tokens by computing equally-weighted market returns, as described in Table 2.[8] At the same time, the NFT market is represented by the number of sales, total sales in USD, and Google searches (see Lin, 2021).

[8] We used an equally-weighted market to avoid the possible effect of large out-performers on our results, as we observed in Section (4.1). Nevertheless, we showed in the supplementary material that the outcome is consistent using the MVI index, which is a cap-weighted index.

4. Empirical results

4.1. Performance: first-day and buy-and-hold (abnormal) returns

We show the main results of this sub-section in Table 4 and Fig. (4), for play-to-earn tokens, Table 5 and Fig. (5), for metaverse tokens, and Table 6 and Fig. (6), for metaverse & play-to-earn tokens.[9]

First, $\overline{R}$ and $\overline{AR}$ are positive when computing the mean, but negative when calculating the median concerning the short-run performance. Consequently, we observed a heterogeneous market where some large out-performers drive positive mean results in the short run, which is in line with the behaviour of the cryptocurrency market (Momtaz, 2021). This outcome is supported by the low percentage of tokens with positive average (abnormal) first-day returns: 40.31% (44.19%) for play-to-earn tokens, 41.67% (42.86%) for metaverse tokens and 35.90% (43.59%) for metaverse & play-to-earn tokens. Therefore, we rejected H1, as traders and gamers should consider the risk of obtaining negative returns on the first trading day.

Second, focusing on the long-run performance, specifically $\overline{BHR}$, we recorded a positive mean and median after the third month for all categories. The percentage of tokens with positive results tended to improve over time, given that more than 65% of tokens had positive results after the first year. Remarkably, considering the entire sample period, metaverse projects (including play-to-earn games) seem to be characterised by high performance, since more than 80% of tokens obtained positive results. This outcome supports the increasing interest of gamers and blockchain companies in play-to-earn and metaverse projects. Thus, we could soon observe more blockchain companies starting new gaming projects and more gamers playing these games expecting to obtain tokens as in-game rewards. Given these results, we did not reject H4 and H5.

Third, from the perspective of traders, we observed that better performance than the entire cryptocurrency market, represented by the CCi30 index, was not guaranteed by the metaverse and play-to-earn niches, given the fluctuations observed with the median of $\overline{BHAR}$ for different holding periods.[10] Thus, we rejected H2. However, we underline that traders focused on this market could find "new winners" that replicate the positive behaviour of past famous projects, such as AXS, MANA, GALA, UFO, SMI, ENJ, JADE, STARL, WEMIX and ILV. Interestingly enough, even though some of these projects are well-known by the gaming industry and the scientific communities (e.g. Axie infinity (AXS) and Decentraland (MANA); see Dowling, 2021a,b), some of them, such as ILV, are still projects in progress[11], which demonstrates the increasing interest in this blockchain niche.

Finally, gamers and traders must consider that the high positive performance and the rapid increase in IGOs observed in Fig. (2) seem to indicate the emergence of crypto bubbles in the gaming industry and a possible market saturation in the future. During this period, we could observe new scams and frauds, such as Squid game crypto tokens (Britton, 2021), and overvalue projects, with consequent losses. Indeed, we observed tokens that had lost more than 50% of their value in our study: 28 play-to-earn tokens (21% of the sample), six metaverse tokens (7% of the sample), and two metaverse and

[9] The short- and long-run performance of all the tokens individually is reported in the supplementary material.

[10] For $\overline{BHAR}$, we observed again the effect of large out-performers, given the positive mean and variant median. Thus, the mean cannot be considered as a proper representation of the market.

[11] According to ILV website, the Open Beta is scheduled for Q1 2022.

play-to-earn tokens (5% of the sample). Therefore, users interested in the crypto gaming industry should also consider the negative side of this market segment, given that, regardless of the overall positive performance of this niche, "all that glitters is not gold."

Table 4: Short- and long-run performance of play-to-earn tokens.

		$\overline{BHR}_\tau$						
Play-to-earn	$\overline{R}$	1 week	1 month	3 months	6 months	9 months	1 year	Entire sample
Mean	0.1213	0.2724	0.4737	1.1789	4.3144	17.2893	65.8121	13.3339
Median	-0.0203	-0.0970	-0.2271	0.0193	1.0211	0.6391	3.3735	0.4049
% of tokens: $R/BHR > 0$	40.31%	38.58%	40.54%	51.56%	60.00%	60.00%	68.75%	61.24%

		$\overline{BHAR}_\tau$						
Play-to-earn	$\overline{AR}$	1 week	1 month	3 months	6 months	9 months	1 year	Entire sample
Mean	0.1187	0.2597	0.3569	0.7970	3.0327	15.3615	63.0613	12.4515
Median	-0.0319	-0.1120	-0.1933	-0.1526	-0.0365	-0.1715	0.9414	0.0573
% of tokens: $AR/BHAR > 0$	44.19%	36.22%	35.14%	39.06%	50.00%	45.00%	62.50%	51.16%
Tokens	129	127	111	64	30	20	16	129

Figure. 4: Histogram of first-day (abnormal) returns (R & AR), and buy-and-hold (abnormal) returns (BHR & BHAR) for play-to-earn tokens.

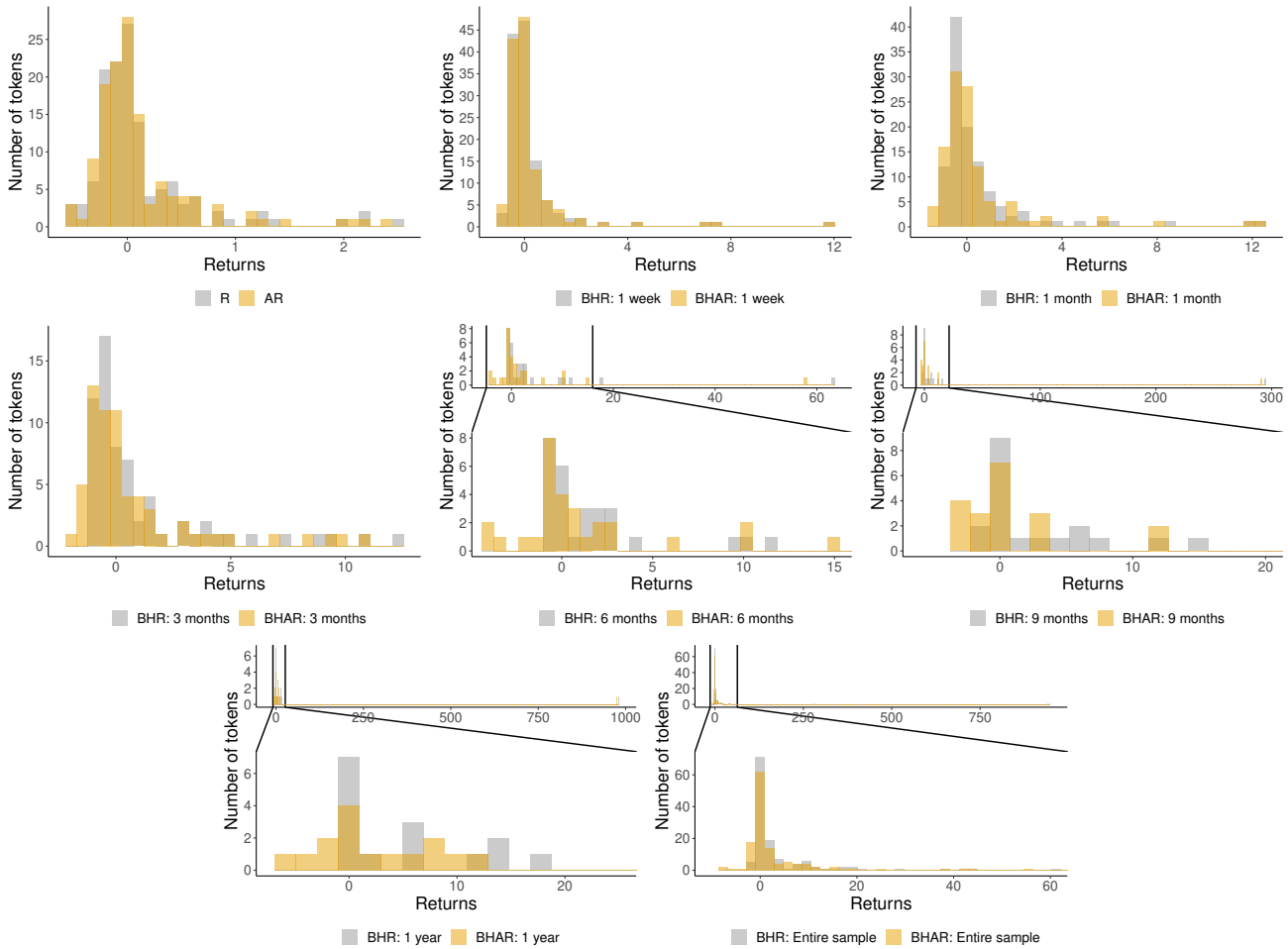


Table 5: Short- and long-run performance of metaverse tokens.

		$\overline{BHR}_\tau$						
Metaverse	$\overline{R}$	1 week	1 month	3 months	6 months	9 months	1 year	Entire sample
Mean	0.1813	0.4397	1.4387	3.2029	4.7285	13.2354	46.7799	33.8304
Median	-0.0175	0.0013	0.1173	0.3417	1.0756	0.9292	1.6124	2.4612
% of tokens: $R/BHR > 0$	41.67%	50.00%	55.26%	60.00%	64.29%	57.14%	65.22%	80.95%

		$\overline{BHAR}_\tau$						
Metaverse	$\overline{AR}$	1 week	1 month	3 months	6 months	9 months	1 year	Entire sample
Mean	0.1797	0.4203	1.3376	2.8176	3.6941	11.3513	44.2077	31.9991
Median	-0.0208	-0.0271	-0.0029	0.2119	0.2371	-0.2752	-0.2419	1.2219
% of tokens: $AR/BHAR > 0$	42.86%	44.05%	50.00%	54.55%	54.76%	42.86%	43.48%	69.05%
Tokens	84	84	76	55	42	28	23	84

Figure. 5: Histogram of first-day (abnormal) returns (R & AR), and buy-and-hold (abnormal) returns (BHR & BHAR) for metaverse tokens.

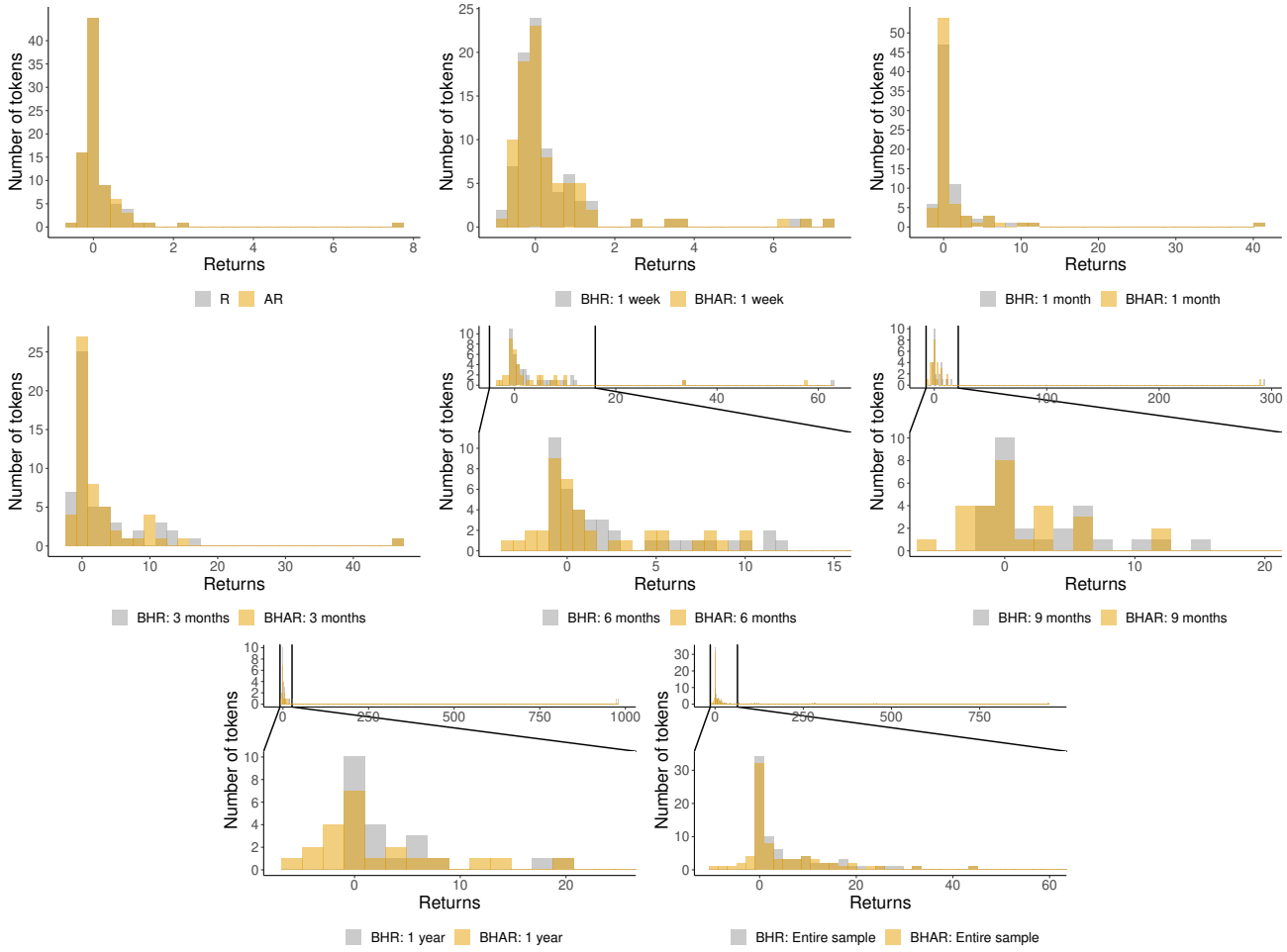
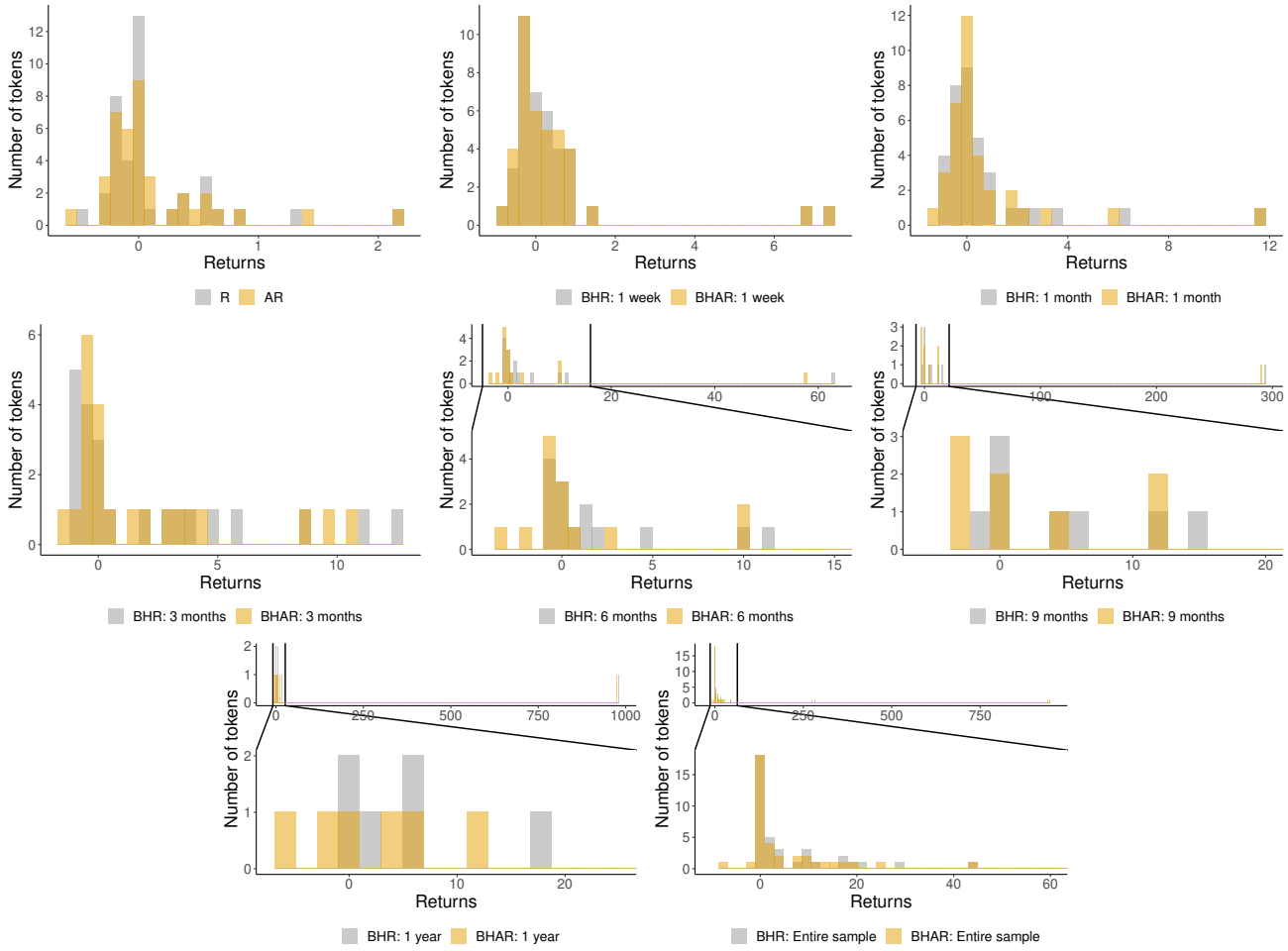


Table 6: Short- and long-run performance of metaverse & play-to-earn tokens.

		$\overline{BHR}_\tau$						
Metaverse & Play-to-earn	$\overline{R}$	1 week	1 month	3 months	6 months	9 months	1 year	Entire sample
Mean	0.1194	0.4372	0.7254	2.2707	6.0990	36.6660	144.3757	37.1050
Median	-0.0195	-0.0177	-0.0663	0.1344	0.8525	4.7509	6.2049	1.2909
% of tokens: $R/BHR > 0$	35.90%	48.72%	48.57%	59.09%	60.00%	66.67%	85.71%	82.05%

		$\overline{BHAR}_\tau$						
Metaverse & Play-to-earn	$\overline{AR}$	1 week	1 month	3 months	6 months	9 months	1 year	Entire sample
Mean	0.1181	0.4331	0.6416	1.8864	4.7933	34.3591	141.0722	35.9645
Median	-0.0139	-0.0147	-0.0978	0.0713	-0.1773	-0.1426	3.9798	0.9033
% of tokens: $AR/BHAR > 0$	43.59%	48.72%	40.00%	50.00%	46.67%	44.44%	57.14%	71.79%
Tokens	39	39	35	22	15	9	7	39

Figure. 6: Histogram of first-day (abnormal) returns (R & AR), and buy-and-hold (abnormal) returns (BHR & BHAR) for metaverse & play-to-earn tokens.



4.2. Dynamics: Pearson and Kendall correlations

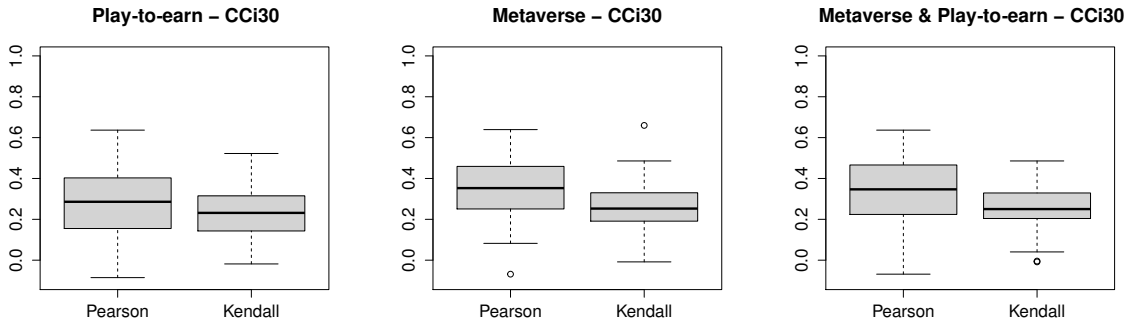
In Table 7, and Fig. (7), we report the Pearson and Kendall correlations between play-to-earn/metaverse tokens and the cryptocurrency market, represented by the CCi30 index. As can be observed, a low co-movement with coefficients around 0.3 is shown. Thus, metaverse and play-to-earn tokens are weakly connected with the behaviour of the cryptocurrency market, allowing traders to use these tokens as diversifiers in cryptocurrency portfolios.[12] The absence of high co-movements with general cryptocurrency behaviour is also interesting for blockchain companies, as such companies could diversify their blockchain product portfolio with metaverse and play-to-earn projects. Consequently, we did not reject H3 and H6.

This result is in line with Dowling (2021b) and Aharon and Demir (2021). Dowling (2021b) observed limited volatility transmission effects between cryptocurrencies and NFT trades from the Axie infinity, Decentraland and Cryptopunks markets. Aharon and Demir (2021) reported that NFTs are mainly shock independent from Ethereum. However, compared to these authors, who analysed NFT trades (i.e., in-game items), we analysed the metaverse and play-to-earn tokens related to these markets (e.g. AXS from Axie infinity). Therefore, as observed with NFT trades, in-game tokens are weakly associated with the cryptocurrency market.[13]

Table 7: Median of Pearson and Kendall correlations: play-to-earn - CCi30, metaverse - CCi30, metaverse & play-to-earn - CCi30.

	Pearson	Kendall	Tokens
Play-to-earn - CCi30	0.29	0.23	111
Metaverse - CCi30	0.35	0.25	76
Metaverse & Play-to-earn - CCi30	0.35	0.25	35

Figure. 7: Box plots of Pearson and Kendall correlations: play-to-earn - CCi30, metaverse - CCi30, metaverse & play-to-earn - CCi30.



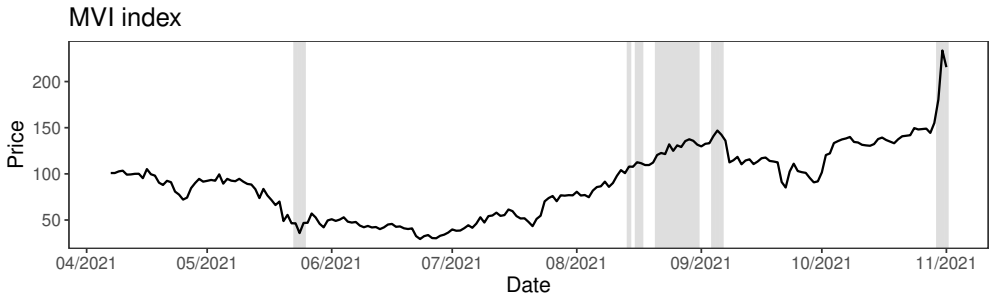
[12] We should consider that, even though these tokens do not outperform continuously the cryptocurrency market (see $BHAR$ in Sec. (4.1)), they do obtain positive results (see BHR in Sec. (4.1)) in the median. Thus, they could be proper investments, specially considering the diversifiers benefits observed in this section.

[13] The list of individual Pearson and Kendall correlations is available in the supplementary material.

4.3. Financial bubble: Backward Sup Augmented Dickey-Fuller test (BSADF)

In Fig. (8) we applied the BSADF test to the Metaverse index (MVI), given that it includes the most relevant play-to-earn and metaverse tokens. Interestingly, we identified a concentration of explosive periods in August and September 2021. After some weeks, the bubble seems to continue in the last days of October 2021. The presence of bubbles should be analysed in more detail in future research due to the considerable increase in IGOs over time and the initial signs of explosive price behaviour.Given this outcome, we did not reject H7.

Figure. 8: Metaverse index (black line) and bubbles detected by the BSADF test considering the 90% critical value (gray areas).



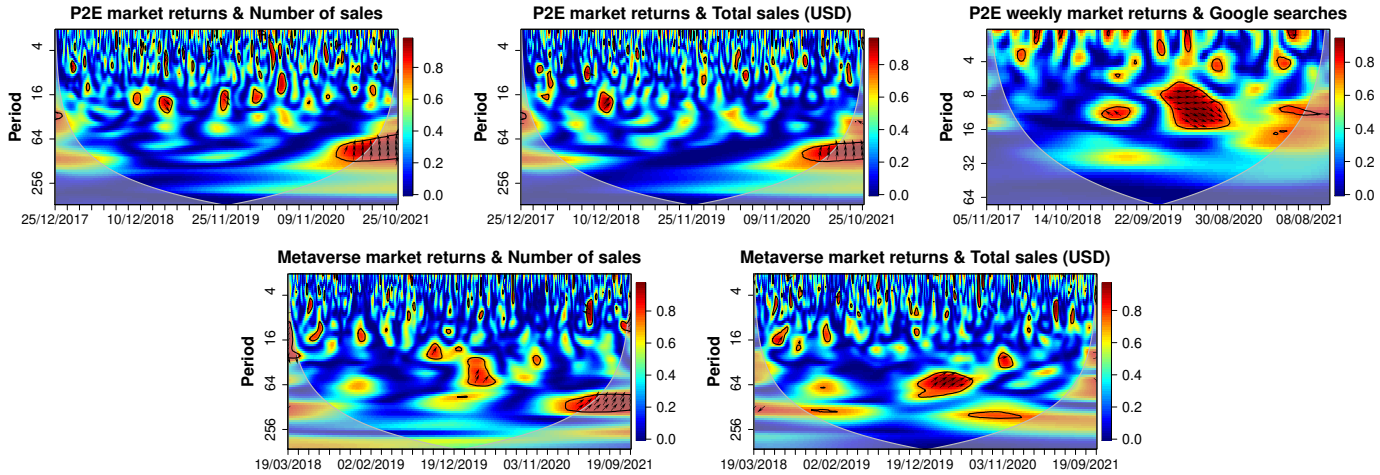
4.4. Market returns and NFT features: Wavelet coherence approach

In Fig. (9), we show the wavelet coherence for the following pairs: (i) "play-to-earn market returns - number of sales", (ii) "play-to-earn market returns - total sales", (iii) "play-to-earn weekly market returns - Google searches", (iv) "metaverse market returns - number of sales" and (v) "metaverse market returns - total sales", where the sample periods are defined by the availability of NFT data, since it is the shortest. Moreover, we did not analyse the pair "metaverse weekly market returns - Google searches" due to the recent investor attention on metaverse projects.[14]

As shown in Fig. (9), we generally reported a low co-movement between market returns and the number of sales/total sales, given the dominance of the blue colour, except for some red areas from June 2021 over the 64-day frequency band. Hence, NFT features and market returns seem to be weakly correlated. In this line, focusing on the pair "play-to-earn weekly market returns - Google searches", we also observed a low co-movement. However, we reported a higher positive correlation from June 2020 to September 2020 in this case, when Googgle searches seem to lead the behaviour of the market, since most of the arrows point downward. Therefore, we did not reject H8, given that market returns are not highly related to the NFT market, i.e. the positive performance reported in previous sections is not explained by NFT sales and investor attention.

[14]Particularly, for metaverse Google searches, we only have 30 observations with values higher than 0. This fact can be observed in Table 2, given that the mean is equal to 1.79.

Figure. 9: Wavelet coherence between plat-to-earn/metaverse market returns and NFT features.



5. Robustness analysis

In this section, we show the robustness of our previous main results dividing the entire sample period into two subperiods to consider the possible effect of COVID-19 on the market.

5.1. COVID-19

Following Aharon and Demir (2021) and Bouri et al. (2021), we analysed the effect of the COVID-19 pandemic on our results by splitting our sample period into two subperiods: pre-COVID-19 and post-COVID-19, and whose cut-off date is set as January 13, 2020.[15] We report the performance and dynamics outcomes in Tables 8 and 9. On the one hand, concerning the performance, we can observe distinctive results when comparing both periods, given the positive performance in the long run ($\overline{BHR}_\tau/\overline{BHAR}_\tau$) after COVID-19. However, this difference does not seem to be connected with the COVID-19 pandemic but with the remarkable increment in metaverse/play-to-earn projects and tokens, as shown in Fig. (2) and Table 8. Therefore, we could state that COVID-19 did not negatively affect the development of this crypto niche.[16]

Table 8: Short- and long-run performance of play-to-earn, metaverse, and metaverse & play-to-earn tokens for the pre-COVID-19 and post-COVID-19 periods. For the sake of space, τ denotes the entire sample period.

	Play-to-earn				Metaverse				Metaverse & Play-to-earn			
Pre-COVID-19	$\overline{R}$	$\overline{BHR}_\tau$	$\overline{AR}$	$\overline{BHAR}_\tau$	$\overline{R}$	$\overline{BHR}_\tau$	$\overline{AR}$	$\overline{BHAR}_\tau$	$\overline{R}$	$\overline{BHR}_\tau$	$\overline{AR}$	$\overline{BHAR}_\tau$
Mean	0.2487	-0.0140	0.2510	0.3594	0.1363	0.4037	0.1403	0.6735	0.6556	0.6475	0.7130	1.1814
Median	0.0415	-0.4787	0.0222	-0.1399	-0.0029	0.1241	0.0064	0.0667				
Positive performance (%)	66.67%	33.33%	83.33%	33.33%	54.55%	54.55%	54.55%	54.55%	100.00%	50.00%	100.00%	50.00%
Tokens	6	6	6	6	11	11	11	11	2	2	2	2
Post-COVID-19	$\overline{R}$	$\overline{BHR}_\tau$	$\overline{AR}$	$\overline{BHAR}_\tau$	$\overline{R}$	$\overline{BHR}_\tau$	$\overline{AR}$	$\overline{BHAR}_\tau$	$\overline{R}$	$\overline{BHR}_\tau$	$\overline{AR}$	$\overline{BHAR}_\tau$
Mean	0.1089	12.1975	0.1065	11.1592	0.1555	29.8282	0.1543	27.6797	0.0855	32.6202	0.0817	31.2339
Median	-0.0264	0.5309	-0.0333	0.1655	-0.0199	3.3726	-0.0171	1.7150	-0.0203	1.9296	-0.0203	1.2307
Positive performance (%)	38.76%	62.79%	41.86%	52.71%	38.10%	83.33%	41.67%	71.43%	33.33%	84.62%	41.03%	74.36%
Tokens	129	129	129	129	84	84	84	84	39	39	39	39

[15] Following Vidal-Tomás (2021), we obtained similar results using March 13, 2020 as our cutoff point (material upon request).

[16] For the sake of space, we only report in Table 8 the long-run performance where τ is equal to the entire sample period. In the supplementary material, we added all the possible periods for τ.

On the other hand, we observed in Table 9 that play-to-earn and metaverse tokens are weakly correlated with the cryptocurrency market regardless of the period, considering the Pearson and Kendall correlations. The observed coefficients were below 0.5. Thus, in line with Aharon and Demir (2021), projects related to NFTs seem to have diversification benefits during the COVID-19 crisis.

Table 9: Median of Pearson and Kendall correlations: play-to-earn - CCi30, metaverse - CCi30, metaverse & play-to-earn - CCi30. Pre- and post-COVID-19 periods.

	Pre-COVID-19			Post-COVID-19		
	Pearson	Kendall	Tokens	Pearson	Kendall	Tokens
Play-to-earn - CCi30	0.44	0.38	5	0.29	0.23	111
Metaverse - CCi30	0.29	0.24	10	0.35	0.27	76
Metaverse & Play-to-earn - CCi30	0.45	0.41	2	0.35	0.25	35

6. Conclusion

Since Nakamoto created Bitcoin in 2008, blockchain technologies have opened a range of new possibilities in many sectors, such as healthcare, logistics and education. The gaming industry seized its opportunity with the prominent emergence of play-to-earn games and metaverses in 2021.

In this paper, we analysed the main properties of this new crypto niche, characterised by continuous growth driven by the interest of gamers, traders and companies. On the one hand, it was shown that play-to-earn and metaverse tokens are characterised by positive performance in the long run, on average. Thus, (i) the gaming activity is compensated by the tokens that users receive while playing, and (ii) blockchain companies could find in this niche an alternative market segment in which to invest, given the positive returns. However, we observed inconclusive results because of market volatility when comparing the performance of these tokens to the cryptocurrency market. Thus, traders could not outperform cryptocurrency market indices with this group of tokens, even though they could find new "golden eggs" that easily outperformed the CCi30 index. On the other hand, concerning the dynamics of this market segment, we reported that the returns of the metaverse and play-to-earn tokens did not co-move significantly with the cryptocurrency market measured by the CCi30 index. As a result, (i) traders could diversify their cryptocurrency portfolios with these tokens, and (ii) blockchain companies could consider new blockchain gaming projects to diversify their product portfolios. Finally, we also demonstrated the existence of price explosive behaviour and the absence of high correlations between market returns and NFT features, which underlines the discrepancies between the financial and real sphere, i.e. the positive performance of metaverse and play-to-earn tokens is not justified by the real evolution of NFT sales and investor attention.

We contribute to the cryptocurrency literature by providing the first insights into this crypto niche. Notably, it is relevant to highlight that the increase in IGOs and the extremely positive performance of some tokens seem to indicate the presence of a new crypto bubble. Thus, researchers and policymakers should continue to analyse the behaviour of this market segment.

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