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Cryptocurrency Dynamics Revealed: Unveiling the Intricate Interaction Between Price, Rewards, and Token Allocation in the Axie Infinity Ecosystem

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Abstract: *This article investigates the relationship between the price of the cryptocurrency AXS, staking reward rates, and token allocation within the Axie Infinity ecosystem. Using Johansen's cointegration tests and Granger causality analysis, we examine weekly data from July 2022 to June 2023. The results reveal a long-term connection between these variables, with the AXS price influencing changes in staking reward rates and token allocation. A temporal delay is observed between price changes and subsequent reactions. Furthermore, a feedback loop is identified between staking rewards and token allocation. These interactions highlight the interplay between financial and engagement aspects within the ecosystem, providing insights beyond the Axie Infinity context.*

Keywords: *Axie Infinity, cryptocurrency, staking, rewards, token allocation, cointegration, Granger causality, interconnection, market dynamics.*

1. Introduction

The convergence of gaming, blockchain technology, and financial opportunities has created a landscape of remarkable interest and investigation, with projects like Axie Infinity standing out. In the context of blockchain technology, this game has gained prominence for revolutionizing the "play-to-earn" paradigm, allowing players to earn real money while having fun (Egliston & Carter, 2023).

Axie Infinity represents an innovation at the intersection of economy, entertainment, and blockchain technology. By enabling players to collect, create, and battle with virtual creatures called "Axies," denominated as "AXS," the platform has introduced a virtual economy where digital assets can be traded, thereby acquiring a new economic role (Huynh-The et al., 2023; Alvaro et al., 2022).

On the other hand, the financial dimension of staking in this ecosystem is also significant. The "staking reward rate" motivates participants to contribute to the network, potentially impacting the price of this cryptocurrency, while the "staking allocation rate" influences the availability of tokens in the market, directly affecting the asset's price (Cong et al., 2022). Understanding how these rates interact with the price of AXS is crucial for deciphering the complex dynamics of the ecosystem.

According to Cong et al. (2022), staking involves locking a certain amount of tokens on a blockchain or decentralized network as part of the network's consensus mechanism. This staking action helps maintain network security and integrity, and participants who stake are rewarded with additional tokens as an incentive, indirectly generating the "staking reward rate," which refers to the rate of reward or return that token holders receive when participating in the staking process on a blockchain or decentralized network.

On the other hand, Cong et al. (2022) highlight that the "staking allocation rate," representing the proportion of tokens currently being staked relative to the total token supply, also plays a crucial role. When a large percentage of tokens are locked in staking, the available supply on the open market is reduced, which can create scarcity and increase the asset's price. In this context, this research aims to answer the following question: What is the causal relationship between the staking reward rate and the staking allocation rate of the AXS coin on the price of this cryptocurrency?

2. Literature Review

2.1. Unraveling the Axie Infinity Ecosystem: Exploring Tokenization, the Metaverse, and the Significance of Governance Staking

In the current landscape, the convergence of gaming, blockchain technology, and financial opportunities has emerged as an area of intense interest and research. The Axie Infinity project, a blockchain-based collectibles game and a prime example of the metaverse, has captured the attention of researchers and enthusiasts. Huynh-The et al. (2023) define Axie Infinity as a game where players can collect, create, and battle with virtual creatures called "Axies," while Alvaro et al. (2022) identify the AXS token as a virtual currency within this ecosystem.

At the heart of this ecosystem lies the unique intersection of entertainment, profitability, and blockchain technology, as highlighted by Aguila et al. (2022). Axie Infinity, conceived by the company Sky Mavis, emerges as a pioneering milestone in a new era of gaming, capable of redefining the relationship between economy and entertainment (Aguila et al., 2022). This becomes even more evident in the words of Juan et al. (2023), who observe how tokenization and blockchain harmonize to give rise to an innovative ecosystem. Here, "Axies" are far more than mere characters in a game; they are key elements for players to earn real money through virtual battles.

This "play-to-earn" approach is substantiated by Juan et al. (2023), who detail how players can acquire in-game tokens like "Smooth Love Potions" (SLP) and "Axie Infinity Shards" (AXS), which can be exchanged for real value. Axie Infinity establishes a unique economy where players can not only have fun but also earn money by buying, selling, and trading digital assets, including the Axies themselves (Juan et al., 2023). The existence of a secondary market for acquiring and trading Axies and other in-game assets further strengthens this industry transformation.

The dimension of governance emerges as a fundamental component in the Axie Infinity landscape, where tokens like AXS play a crucial role. Gadekallu et al. (2022) emphasize how token staking enables holders to actively participate in decisions and be rewarded for their contributions to the ecosystem. This participation is supported by blockchain technology, ensuring transparency and immutability in all governance-related transactions (Gadekallu et al., 2022). This evolution of governance is contextualized by Yu et al. (2022), who explore the transition from centralized to decentralized governance over time.

While Axie Infinity has shown great promise, its implementation also raises questions and challenges. Egliston & Carter (2023) highlight ambiguities regarding the financial viability of the game, noting that despite earning opportunities, not all players achieve economic success. Additionally, the fluctuating values of tokens, as evidenced by variations in Axie tokens, introduce uncertainties (Egliston & Carter, 2023). Yu et al. (2022) also discuss the security challenges that Axie Infinity faces, citing examples of attacks that occurred, such as the loss of over $625 million due to an attack on the Axie Infinity's Ronin sidechain. These attacks underscore the importance of ensuring the security of players' wallets and tokens within the ecosystem.

Furthermore, the perspective of Nguyen & Maine (2023) emphasizes the need to assess losses in the cryptocurrency industry, applying general tax principles and proposing frameworks for appropriate tax deductions. This approach contributes to a comprehensive understanding of the financial and legal implications of these transactions within the context of Axie Infinity and similar projects. Additionally, Rahma's analysis (2023) introduces the ethical and Islamic perspective on in-game transactions, highlighting the dilemma between economic opportunities and Islamic ethical principles. On the other hand, Amantini (2022) raises concerns about the overvaluation of digital assets and the potential for money laundering, prompting critical reflections on the industry.

The Axie Infinity project exemplifies the fusion of blockchain technology, gaming, and finance, giving rise to a new "play-to-earn" approach. The landscape is intricate, connecting players, technology, economy, and entertainment. With the foundation of blockchain, Axie Infinity brings forth a virtual economy where players can not only enjoy but also thrive. However, challenges and debates persist, outlining a complex terrain where prospects for financial success coexist with the realities of a evolving industry. While blockchain technology drives this transformation, ongoing research and investor awareness are necessary to successfully navigate the dynamic landscape of Axie Infinity.

2.2. Consensus Mechanisms and Financial Dimensions in the Blockchain Ecosystem: A Comparative Analysis between Proof-of-Stake (PoS) and Proof-of-Work (PoW)

Blockchain technology has revolutionized various sectors, and consensus mechanisms play a pivotal role in this transformation. Proof-of-Stake (PoS) emerges as an alternative to Proof-of-Work (PoW), presenting advantages and disadvantages that affect its efficiency, security, and decentralization. Additionally, the financial dimensions associated with staking, such as the allocation rate and reward rate, also play a crucial role in the dynamics of cryptocurrency markets. In this context, we will explore these concepts, highlighting both the positive and negative aspects of PoS, as well as the influence of financial dimensions in the cryptocurrency ecosystem.

Proof-of-Work (PoW), one of the pioneering consensus mechanisms, boasts notable advantages, as pointed out by Yu (2023). It is considered fair and secure, allowing any node with computational power to participate in mining and be rewarded with Bitcoins. This establishes a robust system, as competition for computational work prevents malicious actors from compromising network security. Furthermore, PoW provides protection against 51% attacks, as controlling the majority of the network is difficult and costly in practice.

However, PoW also presents significant disadvantages, as highlighted by Wang (2022). Its energy-intensive consumption is a major concern, as mining requires constant competition through complex mathematical problems, resulting in adverse environmental impacts. Additionally, the growth of computational power over time can lead to centralization, threatening the decentralization that is a cornerstone of cryptocurrencies. The high initial costs of hardware can also act as a barrier for new entrants in the ecosystem, as emphasized by Motepalli & Jacobsen (2022).

Proof-of-Stake (PoS), as mentioned by Amantini (2022), brings distinct advantages. It is more energy-efficient, avoiding the intensive competition for computational power. This makes it a greener alternative compared to PoW. Furthermore, PoS has the potential to promote sustainable decentralization, as it doesn't require the same intensive hardware resources, thereby avoiding excessive centralization.

However, it's crucial to consider the disadvantages associated with PoS, as pointed out by Amantini (2022). While PoS aims for decentralization, the initial distribution of cryptocurrencies can lead to wealth centralization in the hands of a small group of early investors. This could result in disproportionate influence over network decision-making, diminishing the intended decentralization. Additionally, the security of PoS is comparatively lower than that of PoW, as proof of stake doesn't involve tangible investments like hardware and electricity, as emphasized by Amantini (2022).

Both mechanisms have their unique advantages and disadvantages, as highlighted by Yu (2023). The choice between them depends on the specific goals of the blockchain and concerns regarding security, energy efficiency, decentralization, and equity. In summary, while PoW excels in robust security, PoS offers energy efficiency, but also faces challenges related to security, decentralization, and inequality. The continuous evolution of blockchain technology will require ongoing evaluation of these positives and negatives to ensure a sustainable and secure ecosystem.

On the other hand, the financial dimension associated with staking is a key element in both Proof-of-Stake (PoS) and Proof-of-Work (PoW) mechanisms, as addressed by Matsunaga et al. (2020), Amantini (2022), and Cong et al. (2022). Motepalli & Jacobsen (2022) emphasize the importance of staking rewards as an incentive to motivate validators to participate honestly in the consensus process and maintain blockchain network security and integrity. The "staking reward rate," as described by Cong et al. (2022), is the reward that staking participants receive for locking their tokens and contributing to the operation and security of the network. This creates a cycle where incentives for staking increase as the staking reward rate increases, impacting both the network economy and token price.

Amantini (2022) emphasizes that the amount of cryptocurrency at stake in PoS can be an incentive for validators to act honestly. Those with more coins have more to lose in case of malicious behavior, creating an incentive to maintain network integrity. Additionally, Amantini (2022) mentions that staking has the potential to promote sustainable decentralization, as it doesn't require the same intensive hardware resources, thus avoiding excessive centralization.

Regarding staking, the allocation rate and reward rate are two critical factors shaping the dynamics of cryptocurrency markets. Cong et al. (2022) note that the reward rate influences token holders' motivation to participate in staking. The more attractive the reward, the more participants will be willing to lock their assets, reducing the available supply in the market and potentially driving up the asset's price.

The staking allocation rate is also vital, as it determines the percentage of tokens currently locked in staking relative to the total token supply. When a significant portion of tokens is staked, the available supply on the market decreases, creating upward pressure on prices (Cong et al., 2022).

Matsunaga et al. (2020), on the other hand, discuss staking rewards in the context of the PoS mechanism. In PoS, validators who contribute to validating new blocks and confirming correct consensuses are rewarded based on the amount of cryptocurrency they hold (their stake). The reward is often determined by the interest rate or dividends offered by the held coins. This encourages coin holding and contributes to the security and efficiency of the PoS system.

In summary, consensus mechanisms like PoS bring important innovations to blockchain technology, offering advantages such as energy efficiency and decentralization, but also presenting challenges like security compared to PoW and potential for centralization. The financial dimensions associated with staking, including the allocation rate and reward rate, play a crucial role in the dynamics of cryptocurrency markets, influencing the supply and demand of digital assets (Matsunaga et al., 2020; Motepalli & Jacobsen, 2022; Amantini, 2022; Cong et al., 2022).

The financial dimension of staking, as addressed by Matsunaga et al. (2020), Motepalli & Jacobsen (2022), Amantini (2022), and Cong et al. (2022), is a fundamental element that influences participants' incentives to contribute to the blockchain network. The staking reward rate and rewards associated with locking tokens are key factors that have the potential to shape validator engagement and system security, while also impacting the prices of digital assets in the market.

3. METHOD

3.1. Data Collection and Preparation

The data was collected daily from the Axie Infinity staking website (stake.axieinfinity.com) and organized into time series of the variables of interest: AXS cryptocurrency price, circulating supply, staking reward rate, and total staked tokens. The measurements were performed on a weekly basis, covering the period from July 2022 to June 2023.

According to Cong et al. (2022), the staking reward rate refers to the rate of return that token holders receive when participating in the staking process on a blockchain or decentralized network. When token holders lock their assets in staking, they contribute to maintaining the security and integrity of the network. In return, they receive rewards in the form of additional tokens, generated by the protocol and distributed to staking participants as an incentive. These rewards can be a fixed percentage of the locked tokens, a portion of network transaction fees, or other incentive mechanisms.

As explained by Cong et al. (2022), "Circulating Supply" refers to the total quantity of units of a digital asset, such as a cryptocurrency or token, that is currently in circulation and available for trading in the open market. In other words, it's the amount of the asset's units held by investors, traders, and users, ready to be bought, sold, or used in transactions. On the other hand, the total quantity of tokens staked refers to the number of tokens of a specific cryptocurrency that have been placed in a process known as staking.

On the other hand, the staking allocation rate, as described by Cong et al. (2022), is calculated as the total quantity of tokens staked divided by the total supply of tokens in circulation. In other words, it's the percentage of the total network tokens that are currently in the staking process.

According to Cong et al. (2022), this rate is an important metric because it directly affects the availability of tokens in the open market. When a significant portion of tokens is locked in staking, there are fewer tokens available for purchase, which can lead to increased demand relative to supply and consequently drive up the token's price. Conversely, if the staking allocation rate is low, more tokens will be available on the market, which can affect the price in a different way.

3.2. Unit Root Test

The unit root test, to assess the stationarity of the time series, was conducted using the Augmented Dickey-Fuller (ADF) test. Three variations of the test were applied: None (No Trend and No Intercept), Const (With Intercept), and Trend (With Trend and Intercept), as demonstrated in equations 1, 2, and 3, respectively.

$$\Delta Y_t = \delta Y_{t-1} + u_t \tag{1}$$

$$\Delta Y_t = \alpha + \delta Y_{t-1} + u_t \tag{2}$$

$$\Delta Y_t = \alpha + \beta t + \delta Y_{t-1} + u_t \tag{3}$$

Where Y_t is the time series, Δ represents the first difference, δ is the lag coefficient, and u_t is the error term, α is the intercept, and β is the coefficient of time trend.

3.3. Johansen Cointegration Test

The Johansen cointegration test is employed to identify long-term relationships among variables. This is represented through the equations of the Vector Error Correction Model (VEC):

$$\Delta Y_t = \pi Y_{t-1} + \rho_1 \Delta Y_{t-1} + \cdots + \rho_{p-1} \Delta Y_{t-p+1} + u_t \tag{4}$$

Where π is the cointegration matrix, ρ_i are the matrices of coefficient of the first difference, p is the lag order, and u_t is the error vector.

3.4. Granger Causality Test

The Granger causality test is applied to identify cause-and-effect relationships among variables. Using the Vector Autoregressive (VAR) approach, the equation is given by:

$$\Delta Y_t = A_1 \Delta Y_{t-1} + \cdots + A_p \Delta Y_{t-p} + u_t \tag{5}$$

Where: ΔY_t is the vector of first differences of the time series. A_i are the autoregressive coefficient matrices, and u_t is the error vector. The test explores whether past information from one time series improves the forecast of the other, indicating Granger causality.

4. Results and Discussions

Table 1 presents a descriptive statistical analysis of the key variables in the study. Each variable is accompanied by its minimum, maximum, and mean values, providing a comprehensive overview of the data distribution. Additionally, the table provides information on skewness and kurtosis, which indicate important characteristics of the distribution shape.

Table1. *Descriptive Statistics of Variables*

Variable	Minimum	Maximum	Mean	Skewness	Kurtosis
Staked Tokens	23,472,294	51,222,934	39,211,641	-0.50	-1.03
Staking Reward	0.36	0.78	0.48	0.97	-0.33
AXS Price (US$)	8.20	9.12	8.81	-1.73	0.86
Circulating supply	66,134,738	98,823,859	89,281,012	-0.83	-1.07
% Staking Allocation	0.35	0.52	0.44	0.14	-0.82
Source: Own Elaboration					

In Table 1, the first aspect examined is the quantity of AXS tokens locked in staking. A varied range between 23,472,294 and 51,222,934 is observed, with an average of approximately 40,034,828. The negative skewness of -0.50 suggests that most of the data is concentrated above the mean, and the excess kurtosis of -1.03 points to a slightly flattened and short-tailed distribution.

On the other hand, the AXS Price has a range from 8.20 to 9.12, with an average of 8.81. The negative skewness (-1.73) suggests a long tail towards higher values, and a positive kurtosis of 0.86 suggests a moderately flattened distribution.

The Circulating Supply of AXS is the total number of AXS tokens currently in circulation in the market. As seen in Table 1, the quantity ranges from 66,134,738.00 to 98,823,859.00 with an average of 89,281,012. The negative skewness (-0.83) and negative kurtosis (-1.07) indicate a flattened distribution with shorter tails.

The Staking Allocation Rate ranges from 0.35 to 0.52 with an average of 0.44. The positive skewness (0.14) suggests a distribution slightly skewed towards higher values. The Staking Allocation Rate, as defined by Cong et al.(2022), refers to the proportion of a given token that is being locked (or "allocated") in the network through the staking process. Staking involves locking a certain amount of tokens in a blockchain or decentralized network as part of the network's consensus mechanism. This staking action helps maintain the security and integrity of the network, while participants who stake are rewarded with additional tokens as an incentive, generating a Staking Reward Rate.

The Staking Reward Rate for AXS, during the analyzed period, ranged between 0.36 and 0.78, with an average of 0.48. The positive excess kurtosis (0.97) indicates a distribution that is flatter and wider than normal, reflecting significant data dispersion, suggesting a trend towards higher values, while the negative excess kurtosis of -0.33 indicates a distribution relatively close to normal.

The variation between 36% and 78% suggests that the reward rate may fluctuate over time or according to specific factors of the staking platform. The average of 0.48 indicates the average annual reward rate that AXS token holders can expect to receive through staking. This means that, during the analyzed period, for each locked AXS token, the holder received, on average, a reward corresponding to 48% of the token's value over a year.

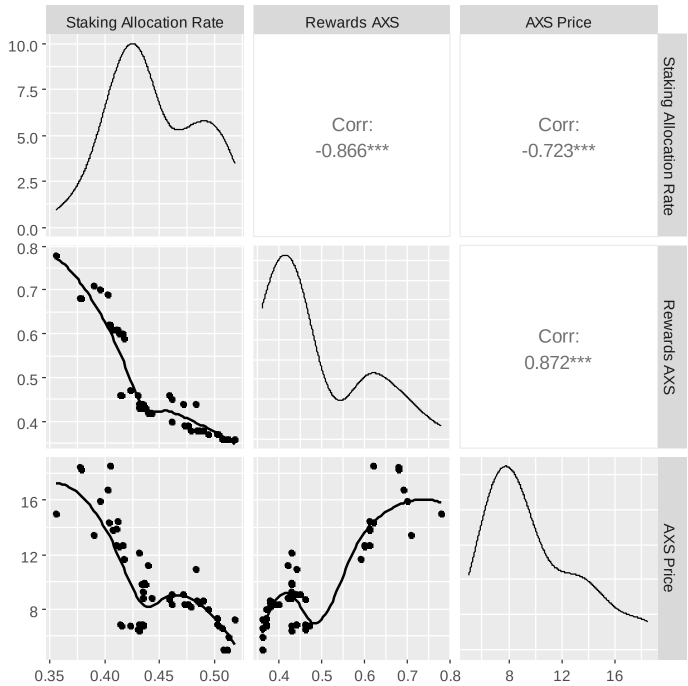

Figure1. *Scatter Plot of Variables*

The analysis of correlations between the variables staking allocation rate, staking reward rate, and AXS price reveals interesting insights into the relationships among these assets in the context of the cryptocurrency market. The correlation matrix presents the following results:

The correlation between the staking allocation rate and staking reward rate has a value of -0.866, indicating a strong negative correlation between these two variables. This suggests that as the staking allocation rate increases, the staking reward rate tends to decrease and vice versa. This may indicate an inverse relationship between these two variables, where higher values of one are associated with lower values of the other.

The correlation between the staking allocation rate and the AXS token price is -0.723, indicating a moderate negative correlation between these two variables. This suggests that as the staking allocation rate increases, the price of AXS tends to decrease and vice versa. However, the correlation is not as strong as the previous one. There might be some degree of inverse relationship between these variables, but it is less pronounced.

Finally, the correlation between the staking reward rate and the AXS price is 0.872, indicating a strong positive correlation between these two variables. This suggests that as the staking reward rate increases, the price of AXS also tends to increase and vice versa. This may indicate a direct relationship between these variables, where higher values of one are associated with higher values of the other. The results of the unit root test are presented next.

Table2. *Unit Root Test for Variables: AXS Price, AXS Staking Reward Rate, and Staking Allocation Rate, on a Weekly Basis from July 2022 to June 2023*

Variable	Transformation	Trend	Const	None
AXS Price	Level Data	-2.655	-2.138	-1,865 *
	Return	-6,918 ***	-6,959 ***	-6,952 ***
AXS Staking Reward	Level Data	-2.798	-2,827 *	-2,962 ***
	1st Difference	-8,607 ***	-8,322 ***	-7,482 ***
Staking Allocation Rate	Level Data	0.143	-5,488 ***	-6,283 ***
	1st Difference	-8,382 ***	-8,313 ***	-8,229 ***

Legend: **10% significance; ** 5% significance; *** 1% significance; Δ% indicates percentage change; 1st Difference indicates the first difference. None: deterministic model without trend and intercept; Const: deterministic model with intercept; Trend: deterministic model with intercept and trend.*

Table 2 presents the results of the unit root test conducted over a time period spanning from July 2022 to June 2023, based on weekly data. The unit root test is a statistical analysis that checks whether a time series exhibits a trend or remains stationary over time. A stationary series is one in which statistical characteristics, such as mean and variance, remain constant over time.

In the table, three variables are under analysis: "AXS Price" (the price of the AXS cryptocurrency), "AXS Staking Reward Rate" (the rate of reward that AXS token holders receive for participating in staking), and "Staking Allocation Rate" (the proportion of tokens being staked relative to the total supply). The analysis was conducted in different forms of the variables: level data, returns, and first difference. Level data refers to the original values of the variables in each time period, returns refer to the percentage variations between values relative to the previous period, and first difference refers to the difference between values in a given period and the value in the previous period.

The hypothesis testing associated with the unit root test is crucial for interpreting the results. The null hypothesis (H0) states that the time series possesses a unit root, indicating a time trend and non-stationary behavior. On the other hand, the alternative hypothesis (H1) suggests that the series is stationary, exhibiting no time trend. Upon analyzing the results, it is observed that level data did not reject the null hypothesis of a unit root, indicating the presence of a time trend in these variables. However, data transformed into returns or first differences rejected the null hypothesis for all forms of testing (None: deterministic model without trend and intercept; Const: deterministic model with intercept; Trend: deterministic model with intercept and trend), suggesting that these transformed variables are stationary, displaying no time trend. Accordingly, the cointegration test was subsequently conducted, as demonstrated in Table 3.

Table3. *Johansen Cointegration Test applied to variables: Percentage Variation of AXS Price, First Difference of AXS Staking Reward Rate, and First Difference of Staking Allocation Rate, based on weekly data from July 2022 to June 2023.*

	Δ% AXS Price Cointegrated with Δ Staking Reward Rate			**Δ% AXS Price Cointegrated with Δ Staking Allocation Rate**			**Δ Staking Reward Rate Cointegrated with Δ Staking Allocation Rate**		
H0	Trend	Const	None	Trend	Const	None	Trend	Const	None
r≤3	0.196	0.199	0.177	0.192	0.193	0.180	0.196	0.190	0.172
	***	***	***	***	***	***	***	***	***
r≤2	0.225	0.226	0.215	0.224	0.226	0.216	0.227	0.220	0.204
	***	***	***	***	***	***	***	***	***
r≤1	0.336	0.335	0.439	0.328	0.328	0.324	0.420	0.271	0.257
	***	***	***	***	***	***	***	***	***
r≤0	0.448	0.448	0.438	0.456	0.457	0.453	0.421	0.409	0.403
	***	***	***	***	***	***	***	***	***

Legend: **10% significance level; ** 5% significance level; *** 1% significance level; Δ%: Percentage Variation; Δ: First Difference; None: deterministic model without trend and intercept; Const: deterministic model with intercept; Trend: deterministic model with intercept and trend. Source: Own Elaboration.*

Table 3 presents the results of a Johansen cointegration test applied to the variables: percentage change (weekly) of the AXS cryptocurrency price, the first difference of the Staking Reward Rate, and the first difference of the Staking Allocation Rate. The cointegration test aims to investigate the existence of long-term relationships between the variables, that is, whether they have a stable long-term relationship despite short-term fluctuations. The analysis is conducted under different model configurations, and the test results indicate the statistical significance of cointegration among the variables for different numbers of cointegration relations (r).

The null hypothesis (H0) of the test is that there is no cointegration among the variables, while the alternative hypothesis (H1) suggests the presence of cointegration. The analysis of the Table 3 results shows that, for all model configurations (Trend, Const, and none), and for all levels of cointegration relations (r≤3, r≤2, r≤1, and r≤0), the null hypothesis was rejected at a 99% confidence level. This indicates that the analyzed variables are cointegrated, meaning that they exhibit a statistically significant long-term relationship for the analyzed period.

These results align with the interconnected nature of the Axie Infinity ecosystem, as discussed in the theoretical framework. The game, virtual economy, and financial dimensions, such as reward rates and staking allocation rates, are inherently linked. The cointegration among these variables suggests that changes in one variable may influence the other variables in the long term.

In particular, the cointegration result between the weekly percentage change (Δ%) of the AXS price and the first difference of the Staking Reward Rate indicates that the AXS price is related to changes in the staking reward rate. The results from Table 3 provide a significant insight: there is evidence that variations in the reward rate can exert influence on the cryptocurrency price. This connection suggests that changes in the staking reward rate can potentially affect the cryptocurrency's value, and this relationship can be explained by the impact that staking rewards have on participant motivation and token availability in the market.

In other words, when the staking reward rate is altered, it can directly impact participants' behavior within the ecosystem. The prospect of receiving additional rewards through staking can serve as a powerful incentive for more token holders to participate in the network. This increased participation can influence both supply and demand dynamics as well as network security.

Simultaneously, these variations in staking reward rates also have implications for the overall token availability in the market. When the reward rate is more attractive, more participants might choose to lock their tokens, reducing the supply available for trading. This reduced supply, combined with potentially growing demand driven by rewards, can create a scenario where the cryptocurrency price tends to rise.

This connection between staking reward rate and cryptocurrency price aligns with the discussions of various authors mentioned in the text. Authors like Cong et al. (2022) and Motepalli & Jacobsen (2022) had already pointed out the crucial role of staking rewards in participant motivation and network security. The study by Egliston & Carter (2023) on the financial viability of Axie Infinity also connects here, as players might consider staking rewards when calculating their participation in the game.

Similarly, the cointegration between the weekly percentage change (Δ%) of the AXS price and the first difference of the Staking Allocation Rate suggests that the AXS price is related to changes in the proportion of tokens being staked relative to the total supply. The results from Table 3 bring forth an intriguing observation: there seems to be a link between the AXS price and variations in the proportion of tokens being staked relative to the total supply. This relationship underscores the relevance of the staking allocation rate in the context of asset price dynamics, aligning with previous considerations.

Essentially, when a substantial portion of tokens is being held in staking, it can directly impact the availability of tokens for trading on the open market. As the supply of available tokens reduces due to staking, potentially increasing demand for AXS could create a situation where supply scarcity exerts upward pressure on the price.

This finding is in line with the discussions of various authors mentioned in the text. Authors like Cong et al. (2022) and Matsunaga et al. (2020) had already pointed to the relevance of staking allocation rate in the supply-demand relationship of tokens. The research by Huynh-The et al. (2023) on the virtual economy of Axie Infinity also finds parallels here, as the staking allocation rate can influence the availability of digital assets within the context of the game.

In summary, the results presented in Table 3 suggest that the proportion of tokens being staked relative to the total supply plays a crucial role in determining the AXS price. This relationship highlights the importance of the staking allocation rate as a key factor in the complex equation shaping asset price dynamics. The analysis of cointegration between the first difference of the Staking Reward Rate and the first difference of the Staking Allocation Rate yields notable results in Table 3, as the null hypothesis was rejected at a 99% confidence level for all model configurations (Trend, Const, and none) and all levels of cointegration relations ($r \leq 3$, $r \leq 2$, $r \leq 1$, and $r \leq 0$). This suggests that the analyzed variables are indeed cointegrated, indicating a long-term relationship.

This cointegration relationship between the two variables holds important implications. It suggests that there is a long-term equilibrium between changes in staking rewards and changes in the proportion of tokens being staked relative to the total supply. This can be interpreted as a market response to the incentives offered by the blockchain network.

When staking rewards increase, participants might be more incentivized to lock their tokens, as the potential for higher gains becomes attractive. This, in turn, can affect the proportion of tokens being staked, as more token holders might opt to participate in the staking process. The opposite relationship could also hold: if rewards decrease, the proportion of tokens being staked might decrease as participant motivation wanes.

In summary, the cointegration analysis between the first difference of the Staking Reward Rate and the first difference of the Staking Allocation Rate indicates that these two factors are interconnected in a long-term equilibrium. This interconnection is crucial to understanding how changes in staking rewards can impact token holder participation in the process and consequently influence the dynamics of the AXS price. These findings reinforce the complexity of interactions within the cryptocurrency ecosystem, where economic and financial factors are intricately linked to blockchain technology and participant behaviors. Given the existence of cointegration between the variables, a Granger causality test was conducted, as demonstrated in Table 4.

Table4. *Granger Causality Test applied to the variables: percentage change of AXS Price, first difference of Staking Reward Rate, and first difference of Staking Allocation Rate, on a weekly basis from July 2022 to June 2023*

Lag	**Δ% AXS Price**	**Δ Staking Reward Rate**	**Δ% AXS Price**	**Δ Staking Allocation Rate**	**Δ Staking Reward Rate**	**Δ Staking Allocation Rate**
	~	~	~	~	~	~
	Δ Staking Reward Rate	**Δ% AXS Price**	**Δ Staking Allocation Rate**	**Δ% AXS Price**	**Δ Staking Allocation Rate**	**Δ Staking Reward Rate**
1	0.765	0.013	0.426	0.782	19.290 ***	173.239 ***
2	0.377	0.002	0.213	0.153	09.166 ***	450.641 ***
3	0.249	0.010	0.431	0.006	04.733 ***	290.309 ***
4	0.461	0.079	0.337	0.010	03.091 ***	202.650 ***
5	0.395	0.060	0.267 **	0.030	02.191 *	153.785 ***
6	2.380 **	0.048	2.112 *	0.041	01.154	148.290 ***
7	1.880 *	0.051	2.758 **	0.031	01.233	133.752 ***
8	3.659 ***	0.082	2.420 **	0.080	00.962	109.429 ***
9	3.163 **	0.137	2.331 **	0.191	00.768	089.490 ***
10	2.619 **	0.147	2.207 *	0.157	00.636	074.295 ***

Legend: **10% significance; ** 5% significance; *** 1% significance; Δ%: Percentage Change; Δ indicates the first difference; ~ indicates: does not Granger cause. Source: Own Elaboration.*

Table 4 presents the results of the Granger Causality Test applied to the variables: the percentage variation of AXS Price (cryptocurrency associated with Axie Infinity), the first difference of Staking Reward Rate, and the first difference of Staking Allocation Rate. This analysis was conducted on a weekly frequency over the period from July 2022 to June 2023. The Granger Causality Test is a statistical technique that aims to determine whether a time series can be used to predict another time series, that is, whether a cause-and-effect relationship exists between the variables. The results of the Granger Causality Test indicate that the null hypothesis of non-causality was rejected for several combinations of variables and lags.

The null hypothesis that the percentage variation of AXS Price does not cause the first difference of Staking Reward Rate was rejected at lags 6, 7, 8, 9, and 10. This suggests that fluctuations in the AXS price are causally related to changes in the first difference of Staking Reward Rate around these time delays. In other words, variations in AXS price can influence changes in Staking Reward Rate in subsequent periods. This can be attributed to the interaction between the economy and entertainment within the Axie Infinity ecosystem. As the AXS price increases, more players might be motivated to participate in staking, seeking higher rewards and contributing to network security and integrity, as mentioned by Gadekallu et al. (2022).

However, this decision-making and action process by participants doesn't happen instantaneously. It might take some time for token holders to perceive and evaluate the AXS price increase as a positive signal and then decide to lock their tokens in the staking mechanism. Hence, the time delay between the increase in AXS price and subsequent changes in staking token allocation suggests that participants require time to process information, evaluate opportunities, and make decisions about locking their tokens.

Regarding the hypothesis that the percentage variation of AXS Price does not Granger-cause the first difference of Staking Allocation Rate, rejection of the null hypothesis is observed at lags 5 to 10. This highlights that fluctuations in AXS price are related to changes in staking token allocation in subsequent periods. This, too, can be attributed to the interaction between the economy and entertainment within the Axie Infinity ecosystem. When the AXS price increases, more players might be motivated to participate in staking, seeking higher rewards and contributing to network security and integrity, as mentioned by Gadekallu et al. (2022).

This relationship not only points to a causal connection but also reveals a pattern of time delay that reflects the complex interaction between the economy and entertainment within this ecosystem. When the AXS price experiences increases, it can trigger a chain reaction within the ecosystem. Price appreciation is an observable and tangible metric that players and token holders can use as an indicator of potential profit opportunities. Thus, when the AXS price increases, more players might be motivated to participate in staking, as they see an opportunity to maximize their rewards and earnings through this mechanism.

This connection aligns with what Gadekallu et al. (2022) discuss about token staking as an incentive for holders to participate in the network and contribute to its security and integrity. The act of locking tokens as part of staking is driven not only by immediate financial rewards but also by the understanding that this action contributes to network stability, thereby increasing its overall value.

The time delay in this context can be explained by the need for players to process available information and make informed decisions. Decision-making in the cryptocurrency and blockchain-based gaming ecosystem doesn't happen instantly. Instead, participants might take some time to evaluate opportunities and consider the implications of their choices.

Finally, the rejection of non-causality between the first difference of staking reward rate and the first difference of staking allocation rate (in a bidirectional manner) was observed. This finding suggests that variations in one of these variables can influence and be influenced by changes in the other variable, in a feedback loop that illustrates the interconnection between financial and engagement aspects within the ecosystem.

The causal relationship in the sense that a change in the first difference of staking reward rate influences the first difference of staking allocation rate can be interpreted considering participants' motivation in the ecosystem. When the staking reward rate increases, token holders are incentivized to lock them and actively participate in the staking process, drawn by the potential higher rewards. This increase in participation can lead to a decrease in the available supply in the market, resulting in a larger allocation of tokens for staking. Therefore, the change in the staking reward can drive a higher token allocation, as mentioned by Cong et al. (2022).

On the other hand, the causal relationship in the opposite direction, where a change in the first difference of staking allocation rate influences the first difference of staking reward rate, can be explained by supply and demand dynamics in the token market. When a higher proportion of tokens are being staked, the available supply in the open market is reduced, potentially creating scarcity. This might even lead to upward pressure on asset prices, including AXS itself. To maintain the incentive for holders to participate in staking, the platform might respond by increasing the staking reward rate as a way to attract more participants and maintain balance between token allocation and market liquidity.

The bidirectional causality between these two variables can thus be understood as a feedback cycle between the financial attractiveness of staking and token allocation. The dynamics of interaction between participants, their asset allocation decisions, and the strategies of the Axie Infinity platform to maintain economic balance contribute to this cycle.

In summary, the identified bidirectional causality highlights that changes in staking reward rate and staking allocation rate are not isolated events but are intrinsically linked. The interdependence between these variables reinforces the complexity of the ecosystem, where financial and motivational factors intertwine to shape the dynamics of digital asset prices, player participation, and network security. This aligns with the convergence of blockchain technology, gaming, and financial opportunities discussed in the theoretical framework, providing a more comprehensive view of the Axie Infinity landscape.

5. Final Considerations

The analysis conducted in this study explored the intricate interaction among the price of the cryptocurrency AXS, reward rates, and staking allocation within the Axie Infinity ecosystem. Based on the results of the Johansen cointegration test and the Granger causality test, a series of significant relationships among these variables were revealed, offering insights into the interconnected dynamics between financial and engagement aspects within this ecosystem.

The cointegration analysis results unveiled the existence of long-term relationships between the AXS price, Staking Reward Rate, and Staking Allocation Rate. This suggests that despite short-term fluctuations, these variables share a statistically significant relationship that transcends more extended time periods. The observed cointegration among these variables reinforces the notion that assets exhibiting this kind of profile demonstrate complex relationships where financial and engagement elements intertwine.

The Granger causality analysis deepened our understanding of these relationships. Notably, it was identified that changes in the AXS price impact the Staking Reward Rate with specific time lags. This suggests that alterations in the cryptocurrency's price can influence subsequent changes in staking rewards. The explanation for this time lag may lie in participants needing to process information and make informed decisions within an ecosystem characterized by financial and engagement choices.

Furthermore, the relationship between changes in the AXS price and the Staking Allocation Rate was confirmed. This highlights that the AXS price is linked to shifts in token allocation for staking, suggesting a connection between financial incentives and network participation. As highlighted earlier, this connection underscores the importance of staking rewards as a motivator for token holders' engagement and network security maintenance.

On the other hand, the bidirectional causality analysis between the Staking Reward Rate and the Staking Allocation Rate unveiled a feedback loop between these variables. This cycle implies that changes in one variable can influence changes in the other, creating a dynamic equilibrium within the ecosystem. This reinforces the perspective that Axie Infinity is not merely a game but a complex ecosystem where financial and motivational aspects are intertwined.

The convergence between the theoretical framework and the results of this research underscores the importance of understanding the intersection of economics, entertainment, and blockchain technology. The unique dynamics of Axie Infinity exemplify how games and cryptocurrencies can synergistically interact, with participants' decisions shaping the game's economy and vice versa.

However, its implications extend far beyond this singular ecosystem. When considering the possibility of similar effects in other assets utilizing Proof of Stake (PoS) and staking as validation tools, the applicability of these findings in a broader context can be explored.

The convergence between blockchain technology, games, and finance outlined in this study suggests that the identified effects might not be exclusive to Axie Infinity. PoS-based digital assets share a fundamental characteristic: the ability of holders to actively participate in network validation and maintenance, often through staking. This inherently linked dynamic between financial motivations and active participation could be a constant in other similar ecosystems.

The results of the cointegration test demonstrate that the interconnectedness among price, staking rewards, and token allocation is a tangible and measurable reality within Axie Infinity. Considering that PoS and staking are essential elements in various protocols and cryptocurrencies, it is reasonable to infer that the identified interactions in this research could manifest in other platforms.

The phenomenon of time lag, for instance, is a feature that can be observed in different environments. The need for participants to process information and make informed decisions is not exclusive to Axie Infinity. In assets where staking is an option, it is plausible that changes in financial incentives lead to subsequent actions with a certain delay as holders evaluate their strategies.

Similarly, the bidirectional causality between staking rewards and token allocation could be a constant in PoS ecosystems. The feedback loop identified here—where changes in rewards influence allocation and vice versa—can apply to other cryptocurrencies that also rely on holders' engagement.

Thus, this study not only enriches our understanding of Axie Infinity but also prompts us to broaden our perspective beyond this specific scenario. The analytical model adopted here, based on cointegration and causality tests, can be replicated in other contexts, enabling the exploration of interactions between financial and motivational variables in different assets.

In summary, the interconnected dynamics emerging from Axie Infinity challenge us to think more expansively about the links between games, finance, and blockchain technology. As we continue to navigate this new territory, it is crucial to consider not only what we can learn from Axie Infinity but also how we can apply these lessons across the ecosystem of PoS-based digital assets, fostering a deeper understanding of the intersection between economic incentives, cryptocurrency valuation, active participation, and the ongoing evolution of blockchain technology.

Referências

Aguila, D. A., Bartolata, J. M., & Estrañero, J. G. (2022). AXEing the axie infinity (AI): The AI of modern gaming, business model Strategem, and global economy towards cryptocurrency era (Doctoral dissertation, College of Liberal Arts and Sciences).

Alvaro, A. Z., Christca, E., Markus, M., Sentosa, R., Kemala, A. P., Kom, S., & Kom, M. (2022). Integration between game and NFT. Conference Paper

Amantini, Daniele (2022) Blockchain and metaverse: the present of the future. Tesi di Laurea in Blockchain and cryptocurrencies, Luiss Guido Carli, relatore Massimo Bernaschi, pp. 29. [Bachelor's Degree Thesis]

Ante, Lennart and Saggu, Aman, Time-Varying Bidirectional Causal Relationships between Transaction Fees and Economic Activity of Subsystems Utilizing the Ethereum Blockchain Network (March 25, 2023). Available at SSRN: https://ssrn.com/abstract=4400040 or http://dx.doi.org/10.2139/ssrn.4400040

Cong, Lin and He, Zhiheng and Tang, Ke, Staking, Token Pricing, and Crypto Carry (March 16, 2022). Available at SSRN: https://ssrn.com/abstract=4059460 or http://dx.doi.org/10.2139/ssrn.4059460

Egliston, B., & Carter, M. (2023). Cryptogames: The promises of blockchain for the future of the videogame industry. New Media & Society, 14614448231158614.

Gadekallu, T. R., Huynh-The, T., Wang, W., Yenduri, G., Ranaweera, P., Pham, Q. V., ... & Liyanage, M. (2022). Blockchain for the metaverse: A review. arXiv preprint arXiv:2203.09738.

Juan, A. A., Perez-Bernabeu, E., Li, Y., Martin, X. A., Ammouriova, M., & Barrios, B. B. (2023). Tokenized Markets Using Blockchain Technology: Exploring Recent Developments and Opportunities. Information, 14(6), 347.

Matsunaga, T., Zhang, Y., Sasabe, M., & Kasahara, S. (2020, December). Reward and penalty mechanism in proof-of-stake consensus algorithm for blockchain. In Proc. 2020 International Conference on Emerging Technologies for Communications (ICETC2020), Virtual, E1-5.

Motepalli, S., & Jacobsen, H. A. (2021, September). Reward mechanism for blockchains using evolutionary game theory. In 2021 3rd Conference on Blockchain Research & Applications for Innovative Networks and Services (BRAINS) (pp. 217-224). IEEE.

Nguyen, Xuan-Thao and Maine, Jeffrey A., Crypto Losses (February 23, 2023). University of Illinois Law Review, Vol. 2024, No. 4, 2024, Available at SSRN: https://ssrn.com/abstract=4431079 or http://dx.doi.org/10.2139/ssrn.4431079

Rahma, M. N. (2023). Transaksi Bisnis Game Axie Infinity Ditinjau dari Etika Bisnis Islam (Studi pada Komunitas Axie Family Kecamatan Bungkal) (Doctoral dissertation, IAIN Ponorogo).

Huynh-The, T., Gadekallu, T. R., Wang, W., Yenduri, G., Ranaweera, P., Pham, Q. V., ... & Liyanage, M. (2023). Blockchain for the metaverse: A Review. Future Generation Computer Systems.

Wang, Y. (2022). Volatility spillovers across NFTs news attention and financial markets. International review of financial analysis, 83, 102313. https://doi.org/10.1016/j.irfa.2022.102313

Yu, J., Zhang, M., Chen, X., & Fang, Z. (2022). SoK: Play-to-Earn Projects. arXiv preprint arXiv:2211.01000.

Yu, Y. (2023). Analysis of POW in Bitcoin and POS in Peercoin. Highlights in Science, Engineering and Technology, 39, 784-788.

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