

Quantitative Analysis of Play-to-Earn Blockchain Games: A Case Study of Axie Infinity

Yiming Lai, Sizheng Fan, and Wei Cai

School of Science and Engineering, The Chinese University of Hong Kong, Shenzhen, China

Email: {yiminglai, sizhengfan}@link.cuhk.edu.cn, caiwei@cuhk.edu.cn

Abstract—Real money trading (RMT) is an activity in which players exchange virtual in-game assets for real-world currency, which is a common practice in Massively Multiplayer Online Games (MMOGs). Some game developers prohibit RMT from potentially impacting their revenue streams, and some players are concerned about its threat to the game’s fairness. Play-to-earn (P2E) can be seen as a form of blockchain-based RMT, and concerns about RMT also exist in P2E blockchain games. In this paper, we aim to gain a deeper understanding of P2E blockchain games through comprehensive analysis of data directly from blockchain. Taking Axie Infinity as an example, we collect 206,050,475 transactions involving 9,391,729 unique wallet addresses to build a player profile. We perform an in-depth analysis to depict the game from macroscopic data and apply an unsupervised clustering method to discover behavior patterns. Our results show that nearly 70% of players engage in the game at a basic level, and most players join the game to earn in-game tokens. Although quite a small part of players manipulates almost all game assets, player skill levels are primarily determined by their playtime rather than whether they are active traders. Nevertheless, the concentration of game assets among a small number of high-level players may pose a long-term sustainability risk to P2E blockchain games.

Index Terms—Real Money Trading, Blockchain Games, Play-to-Earn, Player Behavior, Quantitative Analysis

I. INTRODUCTION

Massively Multiplayer Online Games (MMOGs) have attracted millions of players who spend hours a day playing, socializing, or engaging in in-game business activities. To enhance their game experience, players need various game items, such as items that improve their abilities or allow them to decorate their avatars. However, some players choose to buy the game items they need from other players using real money, rather than earning them through gameplay, due to limited playing time. This phenomenon is called real money trading (RMT). Some game developers believe that RMT is harmful to the in-game economy [1] and negatively affects their income from the game [2]. Consequently, these game developers strictly prohibit RMT behavior, which forces players to turn to the black market. Meanwhile, some players are also opposed to RMT because they are worried that RMT will compromise the game’s fairness [3]. However, some games support RMT and even provide an official trading platform, such as Counter-Strike: Global Offensive and Fantasy Westward Journey. These games attract numerous players and have operated for more than ten years, generating massive revenue as well.

With the development of blockchain technology, play-to-earn (P2E) has emerged as a new business model in blockchain

games. Like RMT that occurs in traditional games, players in P2E blockchain games can sell in-game items for real money. However, blockchain technology offers distinct advantages over traditional games: 1) The blockchain infrastructure provides players with ownership of their game assets. Unlike in traditional online games, where all data are stored on game operators’ servers, players’ game properties bound to their own addresses on the blockchain are maintained by an immutable peer-to-peer network. This ownership feature enables the value extension of game properties beyond a particular game. For instance, players can retain their game properties and in-game relationships even after the cessation of game operation [4]. If all games of Blizzard Entertainment were running on the blockchain, even if Blizzard Entertainment suspends game service in mainland China due to the expiration of current licensing agreements with NetEase [5], players would still be able to play these games. 2) Various blockchain-based applications have led to a relatively more open secondary market for blockchain games. Decentralized exchanges (DEXs) offer users the services of providing liquidity and swapping tokens in an Automatic Market Maker (AMM) mechanism executed by the smart contract, which helps players trade their tokenized game properties (such as gold). The active secondary market adds tremendous liquidity to players’ game assets on the blockchain. One of the most famous P2E games is Axie Infinity¹. According to data from Token Terminal², in July 2021, Axie Infinity’s revenue in the past 30 days reached \$334 million, surpassing the top-grossing game Honor of Kings at that time (\$231 million from Sensor Tower³ data).

While much of the research on RMT and P2E has focused on the overall economy of the game [2] [6], analyzing individual player behavior can also inspire game design. However, current research on P2E player behavior mainly relies on qualitative analysis [7] [8], which can be subjective to some extent. Fortunately, the transparency of the blockchain allows for the direct acquisition of transaction data from P2E players, which can be used for quantitative analysis.

Therefore, in this paper, we aim to conduct a quantitative analysis of P2E games based on data from the blockchain and understand how players participate in P2E blockchain games when RMT is encouraged and whether RMT will lead to

¹<https://axieinfinity.com/>

²<https://tokenterminal.com/>

³<https://sensortower.com/>

unfair advantages in games. We have selected Axie Infinity, the most successful P2E blockchain game, as a case study to explore the magic of P2E. Axie Infinity is the first blockchain game to coin the term P2E and introduce it into the design of blockchain gaming. Its success has led to many follow-up blockchain games adopting P2E as a part of their game mechanics design, providing ample data for our investigation. Our results indicate that the majority of players engage in P2E games to earn in-game tokens, although the extent of their involvement may vary. However, only a small percentage of players actually own the game assets. Interestingly, the data suggests that RMT doesn't seem to have a significant impact on the fairness of the game. Instead, a player's level of skill and time spent playing the game appear to be more closely related to their success, as opposed to frequent trading.

II. RELATED WORK

Blockchain technology was first introduced in 2008 as a fundamental technology for establishing a distributed ledger, as described in the Bitcoin whitepaper [9]. The data stored in this distributed ledger are resistant to modification. Ethereum [10], which evolved from Bitcoin, introduced a crucial new feature: smart contracts, which are open-source programs that are automatically executed on the blockchain. This extension of blockchain technology enabled developers to establish decentralized applications (DApps) that could store data and perform computations in a distributed and secure manner.

The video game industry is well-suited to the immutable nature of blockchain technology, as game items owned by players become non-fungible when operated on the blockchain, providing benefits to players [11]. Blockchain gaming offers many possibilities that are appealing to researchers. Min *et al.* [4] surveyed various types of blockchain games and concluded that blockchain technology can provide benefits such as rule transparency, asset ownership, asset reusability, and user-generated content. CryptoKitties⁴ is widely considered the first blockchain game, and researchers have conducted analyses of it. Jiang *et al.* [12] conducted a network analysis of CryptoKitties and found explanations for its rise and fall. Serada [13] analyzed the practice of collecting "vintage kitties" in CryptoKitties and concluded that breeding them resulted in losses for most players. In addition to CryptoKitties, researchers have explored the mechanics of other blockchain games. For example, the study in [14] selected Aavegotchi⁵ as a case and found that financial factors played vital roles in player engagement. The paper in [15] modeled the interactions between game providers and players in the loot box market of blockchain games to explore their optimal strategies and found that gas fees had a substantial effect on the primary market.

After the CryptoKitties mania, blockchain games lost popularity for a while until the emergence of the P2E business model reignited discussions. Studies such as [7] conducted interviews with P2E players and found that the game was

⁴<https://www.cryptokitties.co/>

⁵<https://www.aavegotchi.com/>

time-consuming and tiring. In [8], data was collected through questionnaires, which revealed players' concerns regarding price manipulation, privacy, and security. However, quantitative analysis of on-chain data to study behavioral profiling remains limited in current research.

III. INTRODUCTION TO AXIE INFINITY

A. Game Mechanics

In 2018, Axie Infinity was released on Ethereum blockchain but did not receive much attention. Over the next two years, game developers added new features, such as new battle systems and the well-known P2E incentive mechanism, to enhance the user experience. In April 2021, game items were migrated to Ronin, an Ethereum sidechain created by the developers to improve infrastructure. To summarize, Axie Infinity is a collecting game inspired by CryptoKitties with extended gameplay and a novel economic system.

1) *Gameplay*: Axie is a digital pet with various appearances and different battle abilities. To fully experience the game, players need at least three Axies to participate in both the battle and breeding systems. The turn-based battle system is similar to Pokemon, where a team of three Axies fights against either bots in adventure mode (i.e., player versus environment, PVE) or another player in arena mode (i.e., player versus player, PVP). Winning battles requires strategic planning, including selecting suitable Axies and tactics. In the breeding system, each Axie has specific genes that affect its appearance and battle abilities. To breed Axies, two parent Axies with specific requirements are needed, and players need to spend two in-game tokens: Smooth Love Potion (SLP) and Axie Infinity Shards (AXS), which are critical to the game economy.

2) *Game Economy*: The cycling of the Axie Infinity ecosystem is driven by three primary game assets mentioned above: Axie, SLP, and AXS. Axie is an NFT backed by the ERC-721 standard⁶. SLP is a utility token that is required for breeding and is burned during the process. Players can earn SLP in PVE mode, with a daily cap, and through winning matches in PVP mode. It's worth noting that SLP can only be claimed every 15 days on the blockchain. AXS functions as a governance token, representing a stake in the Axie Infinity game. It is also necessary in the breeding process, as a fee that goes into the community treasury, which is the address that stores the game's generated revenue.

Fig. 1 illustrates the high-level framework of value transfer in Axie Infinity. Initially, the value of a Ronin wallet comes from the Ethereum ecosystem outside. Players can deposit their Wrapped Ether (WETH) in Ronin using the Ethereum bridge, Ramp⁷, or Binance integration⁸, and start buying and selling items in the marketplace. The value circulation within

⁶ERC-721 is an open standard that describes how to build non-fungible or unique tokens on the Ethereum blockchain.

⁷Ramp is a legal infrastructure that connects the traditional banking world to the blockchain network, including Ronin. It allows users to buy crypto without leaving their wallet.

⁸Binance is one of the famous centralized exchanges, and it provides a service of withdrawing AXS, SLP, or WETH from Binance to Ronin wallet.

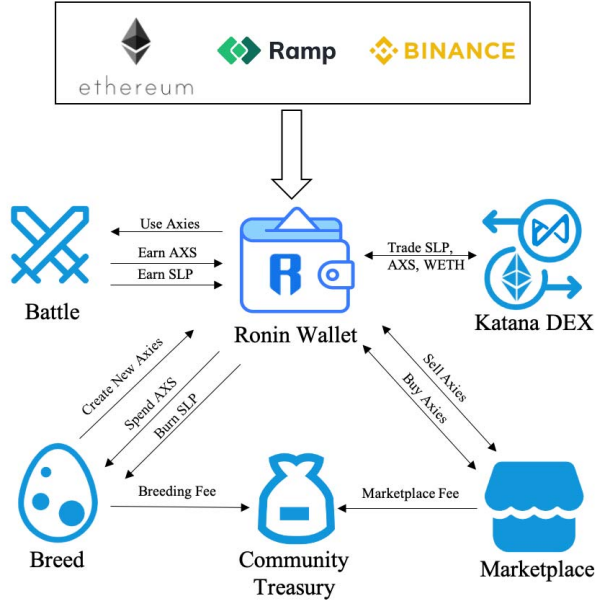


Fig. 1. The Framework of Value Transfer in Axie Infinity

the Ronin ecosystem revolves around the usage and creation of Axies. Players can trade Axies in the marketplace with a 4.25% fee. During the breeding process, SLP is burned, and AXS flows into the community treasury pool as a breeding fee. Breeding fees and marketplace fees comprise most of the game's revenue. In the battle system, players use their Axies to win battles and earn SLP and AXS tokens as rewards for their skilled play by participating in battles. Only the top-ranking players on the leaderboard can earn AXS tokens at the end of each PVP season. Moreover, the DEX named Katana provides a platform for players to trade all tokens in Axie Infinity games. Finally, as a basic function, players can directly transfer their game assets to another wallet address through the Ronin wallet.

B. Scholarship Program

As core game items, Axies are not free for new players. However, the high cost of WETH and the popularity of the game make it difficult for some players to afford the three required Axies. Thus, some players transfer their redundant Axies to another address created by themselves using the Ronin wallet. They then lend this new address to those players in need, requiring a share of the claimed SLP in return. Since only the owner of the private key associated with this address possesses it, it follows that only individuals who initiate transfers of Axies are authorized to handle the corresponding in-game assets. This action is known as a scholarship program, and it was first initiated by Yield Guild Games (YGG), a guild within the game. Players who borrow Axies from others are generally called scholars. Scholarship programs are typically established by individuals or game guilds like YGG and greatly assist new players in entering the game.

IV. DATASET AND METHOD

A. Data Collection

The success of Axie Infinity owes much to the high-performance infrastructure provided by the Ronin blockchain, which has ensured a seamless gaming experience. Therefore, we obtained the open records of addresses interacting with Axie Infinity's contracts on Ronin from April 28th, 2021, to January 27th, 2022, with the assistance of Covalent⁹. This period marks the migration of all game items from Ethereum to the Ronin blockchain and concludes when the hype around Axie Infinity begins to wane. The rise and fall cycle observed during this period provides valuable insights into the dynamics of the game. Throughout this period, a series of adjustments were made to both the battle and economic systems, which offer us an opportunity to analyze players' behaviors and decision-making processes.

As shown in Fig. 2, decoded log events of four smart contracts addresses related to core gameplay were collected block by block. After that, we obtained transaction records of every studied contract via grouping and synthesizing according to transaction hashes. Next, we regrouped these transactions based on player wallet addresses to get player behavior in chronological order. Finally, we extracted the features of interest for further study on the basis of each player's wallet address. The data involve 206,050,475 transactions and 9,391,729 unique wallet addresses.

In order to investigate the connections between daily user activities and other factors which are not shown directly on the Ronin blockchain, we also collected some open-source daily data observed by others in this period, including AXS price in USD from CoinGecko¹⁰, Axie floor price and revenue of the game from community¹¹.

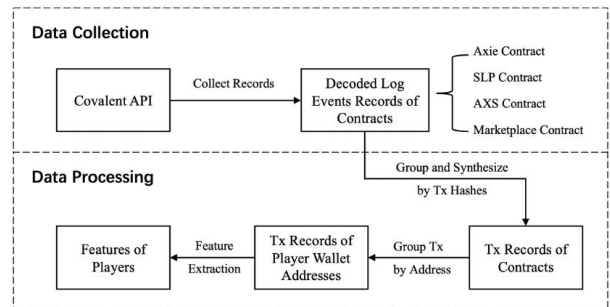


Fig. 2. Data Collection and Processing Process

B. Feature

As illustrated in Section III, the circulation of tokens and Axie is the main component of game economy. Therefore, our main goal is to figure out how each player's wallet interact

⁹<https://www.covalenthq.com>

¹⁰<https://www.coingecko.com/>

¹¹Source from the Twitter user @maxbrand99 and Axie World at <https://www.axieworld.com/en/economics/charts?chart=revenue>, respectively.

with tokens and Axies so that contributes to the whole game ecosystem in this period. Based on the information (including action, value, and timestamp) in transaction records of each player’s wallet address, a total of 11 features were extracted and presented as following:

- **Frequency of Claiming SLP:** Number of times a player invoking "Claim SLP" function.
- **Volume of Claimed SLP:** Total volume of SLP claimed by a player.
- **Frequency of Transferring SLP:** Number of times a player invoking "Transfer SLP" function.
- **Volume of Transferred SLP:** Total volume of SLP transferred by a player.
- **Frequency of Transferring AXS:** Number of times a player invoking "Transfer AXS" function.
- **Volume of Transferred AXS:** Total volume of AXS transferred by a player.
- **Frequency of Breeding:** Number of times a player invoking "Breed Axies" function.
- **Frequency of Sell:** Number of times a player invoking "Create Axie Sale" function.
- **Frequency of Purchase:** Number of times a player invoking "Buy an NFT" function.
- **Frequency of Transferring Axie:** Numbers of a player invoking "Transfer Axie" function.
- **Duration:** Days of a player has stayed in the game.

C. Clustering

In this study, we employ the k-means algorithm for unsupervised clustering, which is widely used in various scenarios. The objective function of k-means is to minimize the total distance between all patterns and their respective cluster centers [16]. Specifically, it is useful for gaining insights into the general distribution of behaviors in a game’s population and notable helpful in checking asset use and game balance [17]. Prior to clustering, we performed zero-mean normalization to mitigate the impact of data type mixing. We conducted experiments on different parameter settings and determined that manually setting the number of clusters to $k = 7$ was the optimal choice.

V. RESULT AND ANALYSIS

A. Daily Statistics

The operational status of a game can be effectively measured by daily statistics, such as daily active users (DAU). This is particularly true for online games, including free-to-play (F2P) games, as well as the Play-to-Earn (P2E) blockchain game examined in this study. Fig. 3 illustrates the daily statistics of Axie Infinity from a macro perspective. New and active players, together with changes in AXS price, are shown in the above figure. The middle section of the figure displays the variation in the Axie floor price, which is the minimum cost of entry into the game. Finally, the graph at the bottom illustrates the game’s unstacked revenue, which consists of marketplace fees and breeding fees. During the study period, the game developers implemented various gameplay balance

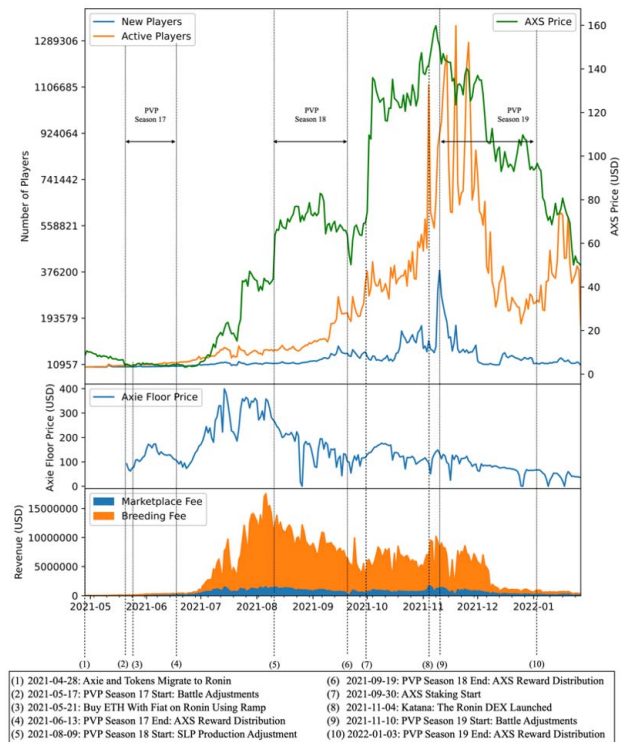


Fig. 3. Daily Statistics

and economic adjustments, some of which had a significant impact on the game’s development. These adjustments are presented chronologically in Fig. 3.

Prior to (4) 2021-06-13, this was the period when all game assets began operating on Ronin. During this period, PVP season 17 was conducted with several battle balance adjustments. Despite this, all metrics remained relatively stable except for the Axie floor price, which experienced significant fluctuations following the launch of the Ronin fiat gateway through Ramp. This event marked a major economic adjustment, allowing players to purchase ETH directly with fiat deposited on Ronin, bypassing the need to obtain ETH first on Ethereum and then transfer it to Ronin. As this occurred during the construction phase following the migration of game assets to Ronin, many players were still observing and deciding whether to participate in the Ronin migration.

From (4) 2021-06-13 to (5) 2021-08-09, Axie Infinity experienced an explosive growth period, with AXS price, Axie floor price, and revenue all increasing rapidly. Furthermore, these metrics exhibited a similar trend, with two peaks appearing almost simultaneously. Though there was no clear indication from the game content updates that could explain this rapid development, we conjecture that two factors may have contributed to this phenomenon: 1) lagging effects of game updates before. The launch of the high-performance Ronin

blockchain infrastructure and more accessible entrance to purchasing NFTs with fiat using Ramp facilitated a smoother and more convenient user experience, attracting a greater number of players compared to the Ethereum period. 2) Frequent exposure to media. When the first peak began to appear, some media noticed the huge trading volume of Axie NFT, which even surpassed some traditional NFT prototypes (e.g., OpenSea, CryptoPunks) [18]. In their coverage, they also introduced the concept of P2E to the public. By the end of July 2021, the single-day income of Axie Infinity surpassed the average daily gain of the most-grossing traditional F2E game, Honor of Kings. News like that quickly spread on the Internet when it was the time that the second peak emerged. Similar to a previous study on CryptoKitties in [12], media exposure has significantly contributed to this explosive growth.

PVP season 18 was held during (5) 2021-08-09 and (6) 2021-09-19, which resulted in a significant fluctuation of AXS price. Initially, it dramatically increased from \$41 to \$70, remaining at a relatively high point until the end of the season when it dropped back to \$50, still higher than the initial price. Since certain amounts of AXS were released after each PVP season, we can infer that PVP seasons provided chances to speculate on AXS, and players who ranked high on the leaderboard tended to sell their AXS rewards rather than keep them as a share of the game.

AXS staking was introduced on (7) 2021-09-30, resulting in a surge in AXS price from \$69 to \$136 in 5 days, with an increase in active players at a higher speed than that of the previous time. The following launch of Ronin DEX on (8) 2021-11-04 led to a remarkable increment in daily active and new players, reaching peaks at 1,348,600 and 382,642, respectively. Not long after that, PVP season 19 started on November 10, 2021, but AXS price, the number of active and new players began to decline, and the significant decrease of AXS price at the end of this PVP season repeated just as PVP season 18 did. It can be conjectured that players were more interested in the financial incentives of the game instead of competing in the arena to win the PVP season rewards.

As the revenue graph at the bottom of Fig. 3 illustrates, the fluctuations in the revenue have a certain correlation with Axie floor price. Moreover, the breeding fee is the main contributor to revenue, rather than the marketplace fee. It implies that most revenue of this game is generated from the creation of Axies, which is a consequence of a large number of new players joining in and the rise of AXS governance token price. As demonstrated above, economic adjustments made to encourage RMT have been successful in attracting a large number of players and increasing the value of AXS, highlighting the potential of an open market for in-game assets in boosting game revenue.

Therefore, based on the observation of daily statistics above, we conclude that: (1) Economic adjustments like increasing market liquidity significantly impact the game ecosystem, compared to battle balance adjustments. (2) The pursuit of for AXS rewards in each PVP season can lead to fluctuation in the AXS price, creating opportunities for speculation on this

token. (3) The major part of revenue comes from the breeding fee rather than the marketplace fee, which means the income of this game mainly depend on the demand for new Axies and the value of AXS token.

B. Cluster Results

In this subsection, we adopt the strategy of converting cluster results to descriptive behavioral profiles [17] [19] to demonstrate our findings. Through a comparison of the playing behavior features scores across different clusters, we can discern distinctive characteristics for each identified cluster. The interpreted behavioral clusters are shown in Table I.

TABLE I
INTERPRETED BEHAVIORAL CLUSTERS

Title	Number of Addresses	Percentage	Characteristics
Dabblers	6,531,634	69.5467%	The lowest score in all features, especially in SLP claim frequency and volume, plus duration.
Light SLP Farmers	1,785,818	19.0148%	Mainly participate in SLP farming without other activities.
Heavy SLP Farmers	1,027,388	10.9393%	Similar to light SLP farmers, with longer duration and highest SLP claim times and volume among all.
Normal Players	41,558	0.4425%	Participate in all activities with a medium value.
Ordinary Axie Breeders	3429	0.0365%	High in breeding, selling and transferring Axies.
Crazy Axie Breeders	410	0.0044%	Extremely high in breeding, selling, and transferring Axies.
Axie Speculators	1,492	0.0159%	Highest in buying Axies and third rank in selling Axies. High in transferring Axies too.

Dabblers refer to the addresses with minimal engagement in the game, representing the majority of total addresses at 69.5467%. Compared to other clusters, dabblers exhibit the lowest scores across all 11 features, with particularly low levels of SLP claiming frequency. They also have the shortest lifespan within the game, indicating limited interest in continued gameplay.

Light SLP Farmers comprises 19.0148% of total addresses, and is characterized by their primary engagement in SLP claiming activities. Their primary goal in playing the game is to earn SLP, which is a crucial element of the P2E mechanism. However, due to their relatively short lifespan within the game, both the frequency and volume of SLP claimed by light SLP farmers remain at a moderate level.

Heavy SLP Farmers are the addresses that act similarly to light SLP farmers, except for their more intensive engagement. These addresses take up 10.9393% of all. They have claimed SLP the most times and obtained the most SLP as well. Furthermore, compared with light SLP farmers, they have stayed in the game for a longer time.

Normal Players refers to the cluster of addresses that participate in various game activities at a relatively balanced level, accounting for 0.4425% of all addresses. Unlike the aforementioned clusters, this group exhibits a more diverse range of actions within the game, with active engagement in Axie interactions like frequent breeding, selling, and buying.

Ordinary Axie Breeders refer to the addresses that are observed to frequently breed and sell Axies, comprising only 0.0365% of total addresses. In addition, they exhibit a relatively low value in SLP claim frequency but high in total claimed value on the contrary. It can be conjectured that some of them have outstanding skills in battling in the game since they have to be aware of which kinds of Axies are highly in demand because of being more competitive in PVP mode.

Crazy Axie Breeders exhibit behavior patterns are similar to ordinary Axie breeders, different from that they perform in extremely high frequency. Crazy Axie breeders only take up 0.0044% with a number of 410 addresses, but they have bred 2187 Axies on average, which is four times more than that of Ordinary Axie Breeders on average. It is notable that they show little interest in farming SLP. Furthermore, they are the most active addresses to transfer AXS. It can be conjectured from their behaviors that they consist mainly of the members from game guilds like YGG.

Axie Speculators encompasses addresses that engage in the most frequent buying and selling activities, accounting for 0.0159% of the total addresses. Their high frequency of trading suggests that these addresses are driven by an interest in speculating on the value of Axies.

C. Analysis of Clusters

In this subsection, we will discuss the similarities and differences among seven clusters.

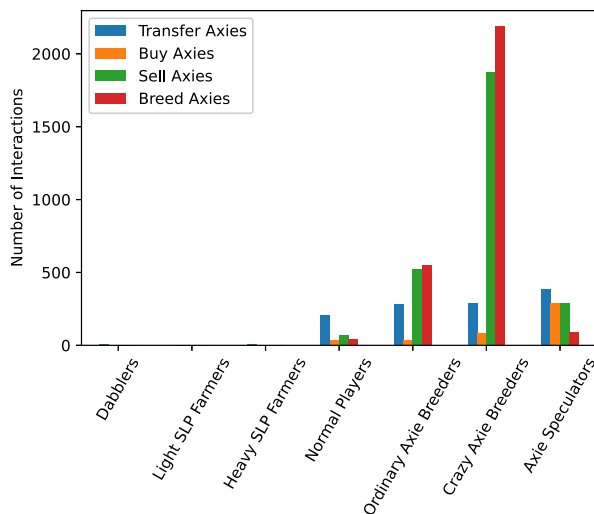


Fig. 4. Average Axie Operations of Clusters

1) *The Effects of Scholarship Programs on Clusters:* Transferring Axies is an essential step for initiating scholarship

programs, making it a vital indicator for scholarship providers. Fig. 4 illustrates the average number of interactions with Axies for seven clusters, where the first three clusters (dabblers, light SLP farmers, and heavy SLP farmers) have made hardly any transfers, with no more than 10 transfers each. However, the latter four clusters (normal players, ordinary Axie Breeders, crazy Axie Breeders, and Axie Speculators) have made significant numbers of transfers, with at least 208 for normal players. This substantial difference in Axie transfers suggests that the first three clusters mainly consist of scholars, while addresses in the latter four clusters are scholarship providers to some degree. Notably, as Table. I indicates, these scholars account for 99.5007% of all addresses, implying that around 99% of addresses do not truly own Axie assets but merely borrow them. In contrast, the remaining 0.4993% of addresses have the most substantial control over Axies in the game.

Like transfer, the purchase, sale, and breeding of Axies are primarily carried out by scholarship providers. These activities are essential contributors to the game's revenue, indicating that the practice of RMT is not harmful but essential to the income of P2E blockchain games. The scholarship programs have expanded the game's player base, but this has resulted in the majority of Axie creation and trade being limited to a small number of addresses, which may not bode well for a sustained, active market.

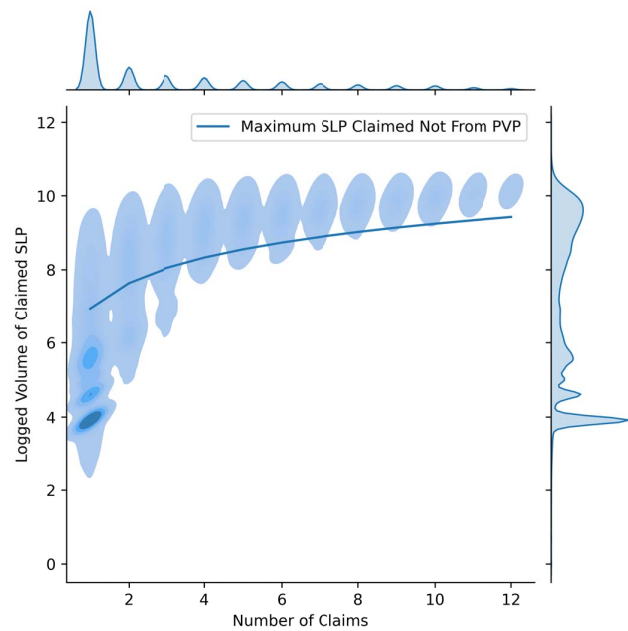


Fig. 5. Density Distribution of the Number of SLP Claims And Corresponding Logged Claimed Volume

2) *SLP Farming Status of Clusters:* In Section III.A, we outlined the specific limitations of obtaining SLP, which makes it possible to judge the battle skills of players based on SLP farming. Fig. 5 presents the density distribution of the number of SLP claims and logged claimed volume. The blue line

represents the maximum logged volume of SLP that can be claimed from battles against bots only. Since winning the battle against bots is much easier, we can consider the addresses above the blue line as skilled players, while those below lack skills. It is observed that skilled players tend to make up a larger proportion of addresses with increasing claim frequency, indicating that players can become proficient in the battle system with practice. We can infer that despite the complexity of combat strategies and varying abilities of Axies, it is not so difficult for players to start with the battle system as long as they invest sufficient time.

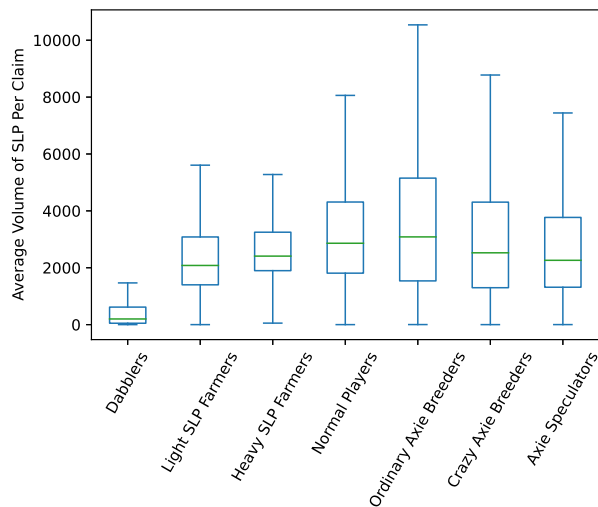


Fig. 6. Average Volume of SLP Per Claim Among Clusters

In contrast, many addresses struggle with battles, as evidenced by the darkest core area in Fig. 5, where SLP claims are infrequent and low in volume. This group only claims SLP once, with an average volume of no more than 60, far below the skilled player baseline of 1035. As shown in Fig. 6, these addresses mainly belong to the dabbler cluster. Although the game is easy to get started with and has a reputation for offering profitable in-game tokens, approximately 70% of addresses lose interest in playing for an extended period. This may indicate that the battle mechanism design is not appealing to potential players.

Apart from dabblers, the clusters exhibit similar game skills, with an average volume of SLP per claim at 3123, three times larger than the baseline of 1035. This suggests that most addresses in these clusters are skilled players. Besides, these six clusters exhibit a similar distribution of players with different game skills, which implies that whether a player is rich in Axies or not, it is relatively fair for players to compete for rewards in the game. This also indicates that, if well-designed, RMT will not result in a pay-to-win scenario.

Fig. 7 shows the summed volume of claimed SLP for each number of claims among all addresses. Although Fig. 5 suggests a large population of dabblers, it is notable that this group contributes little to the production of the SLP token.

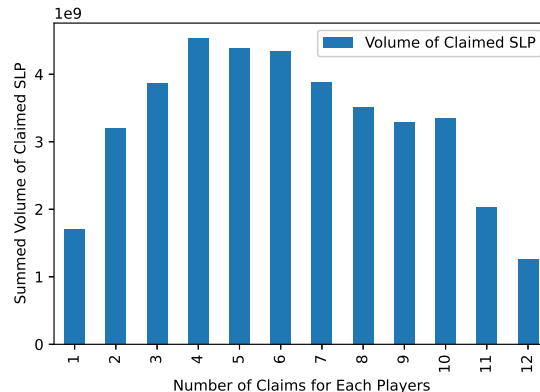


Fig. 7. Summed Volume of Claimed SLP and Corresponding Number of Claims Among All Addresses

Most SLP tokens come from addresses that have been active in the game for at least 30 to 150 days. This suggests that although dabblers have an advantage in population, their poor productivity in SLP tokens may result in price manipulation and inflation caused by a minority of addresses with high production. As a result, dabblers may find it difficult to earn rewards as the game loses its economic appeal, leading to a decline in their engagement with the game.

VI. DISCUSSION

Just as the name of P2E implies, the objective of P2E gaming is primarily centered around earning rewards. From the observation of daily statistics, the adjustments of battle gameplay did not work to attract more players. On the contrary, the continuous economic updates significantly impacted the increase of active and new players. Take F2P games as a comparison, most of which attract players by free entry at first and succeed in continuous gameplay updates for a long time. The development of F2P focuses on 'play' in the long run, while P2E emphasizes the concept of 'earn'. The demand for new gameplay content or continuous game economic incentives is considerably high; otherwise, many players will churn because the game is no longer profitable. Thus, P2E blockchain games should keep updating financial incentive mechanisms or create an economic model that can help the game ecosystem recycle all the time actively. However, either intriguing gameplay content or sustainable game economies are challenging tasks for every game designer.

As the clustering result suggests, most players earn by farming the SLP token, which is, in other words, a game resource with specific utilities. To some extent, it is another version of RMT in traditional online games. However, compared with conventional RMT patterns that it is a tradeoff between costing real money and spending time in the game for items, game resources on blockchain have extended values beyond their original game and tremendous liquidity in the secondary market in nature. Meanwhile, the value of game

resources on the blockchain is also influenced by the whole blockchain ecosystem, making it difficult to determine their earning potential.

Although the original motivation of every player is to earn SLP, the production of SLP from the largest group of players accounting for approximately 70%, is much fewer than that of the remaining part. The minorities have powerful control of the SLP token supply. This pattern is also observed in the production and trade of Axies, which is primarily driven by a smaller fraction of players. The big players dominate the game, similar to the findings in CryptoKitties [12], which is a potential risk for the game. From this perspective, the scholarship program is a double-edged sword, which can make P2E blockchain games popular and simultaneously accelerate the formation of big players. Thus, the P2E blockchain game faces a similar dilemma to that of the RMT phenomenon in traditional games, even worse: it is hard to control the supply and demand of those game resources. Inflation is more likely to occur due to these gold farmers, further disrupting the game's economic system and finally making it no longer profitable.

VII. CONCLUSION AND FUTURE WORK

In this paper, we attempt to picture the distribution of players and understand how they participate in P2E blockchain games. To achieve this, we collected a significant amount of transaction logs from Axie Infinity, a typical P2E blockchain game. After extracting features from the individual player, we applied unsupervised clustering to figure out the behavior profiles of players. Then we showed the daily statistics from a macro perspective and descriptive behavioral cluster results. We observe that the economic adjustments that assist RMT significantly impact the game's development rather than battle balance adjustments, which means the economic factor is the main attraction to potential players. Almost all players come to this game to farm in-game tokens, while Axies which are farming tools, are only manipulated by very few players because of scholarship programs. Although Axies can be traded with real money, this game is relatively fair to all players as long as they actively participate. However, taking the evolution of CryptoKitties as a reference, the behaviors of these emerging big players might threaten the sustainability of P2E blockchain games. Even though Axie Infinity is not mature enough in its game mechanics design, it still provides innovations that the support of RMT based on blockchain systems can benefit game developers and players without compromising game fairness.

Governance tokens are critical vouchers that embody the principles of self-governance in the blockchain community. However, recent studies [20] suggest that they may not be functioning optimally within DeFi protocols. Moreover, in Web3 communities, some DApps distribute governance tokens to members who have made significant contributions, but this has also attracted many speculators who only seek financial gain [21]. Similar governance token mechanisms are also used in P2E blockchain games to incentivize player participation.

As part of future research, we plan to investigate the effectiveness of governance tokens in P2E games and how players of different types respond to them.

ACKNOWLEDGMENT

This work is supported by Shenzhen Science and Technology Program (Grant No. JCYJ20210324124205016)

REFERENCES

- [1] J. Tao, J. Lin, S. Zhang, S. Zhao, R. Wu, C. Fan, and P. Cui, "Mvan: Multi-view attention networks for real money trading detection in online games," in *Proceedings of the 25th ACM SIGKDD International Conference on Knowledge Discovery & Data Mining*, pp. 2536–2546, 2019.
- [2] E. Castronova, "A cost-benefit analysis of real-money trade in the products of synthetic economies," *Info*, 2006.
- [3] I. Constantiou, M. F. Legartha, and K. B. Olsen, "What are users' intentions towards real money trading in massively multiplayer online games?," *Electronic Markets*, vol. 22, no. 2, pp. 105–115, 2012.
- [4] T. Min, H. Wang, Y. Guo, and W. Cai, "Blockchain games: A survey," in *2019 IEEE conference on games (CoG)*, pp. 1–8, IEEE, 2019.
- [5] "Blizzard entertainment and netease suspending game services in china." <https://investor.activision.com/news-releases/news-release-details/blizzard-entertainment-and-netease-suspending-game-services>.
- [6] O. Alam, "Understanding the economies of blockchain games: an empirical analysis of axie infinity," 2022.
- [7] S. B. De Jesus, D. Austria, D. R. Marcelo, C. Ocampo, A. J. Tibudan, and J. Tus, "Play-to-earn: A qualitative analysis of the experiences and challenges faced by axie infinity online gamers amidst the covid-19 pandemic,"
- [8] R. Francisco, N. Rodelas, and J. E. Ubaldo, "The perception of filipinos on the advent of cryptocurrency and non-fungible token (nft) games," *arXiv preprint arXiv:2202.07467*, 2022.
- [9] S. Nakamoto, "Bitcoin whitepaper." <https://bitcoin.org/bitcoin.pdf>.
- [10] G. Wood, "Ethereum: A secure decentralized generalised transaction ledger." <https://ethereum.github.io/yellowpaper/paper.pdf>.
- [11] W. Cai, Z. Wang, J. B. Ernst, Z. Hong, C. Feng, and V. C. Leung, "Decentralized applications: The blockchain-empowered software system," *IEEE Access*, vol. 6, pp. 53019–53033, 2018.
- [12] X.-J. Jiang and X. F. Liu, "Cryptokitties transaction network analysis: The rise and fall of the first blockchain game mania," *Frontiers in Physics*, vol. 9, p. 57, 2021.
- [13] A. Serada, "Vintage cryptokitties and the quest for authenticity," in *2021 IEEE Conference on Games (CoG)*, pp. 1–10, IEEE, 2021.
- [14] Y. Jiang, T. Min, S. Fan, R. Tao, and W. Cai, "Towards understanding player behavior in blockchain games: A case study of aavegotchi," in *Proceedings of the 17th International Conference on the Foundations of Digital Games*, FDG '22, (New York, NY, USA), Association for Computing Machinery, 2022.
- [15] Y. Jiang, S. Fan, and W. Cai, "Economic analysis of loot box market in blockchain games," in *Proceedings of the Fourth ACM International Symposium on Blockchain and Secure Critical Infrastructure*, pp. 35–46, 2022.
- [16] T. W. Liao, "Clustering of time series data—a survey," *Pattern recognition*, vol. 38, no. 11, pp. 1857–1874, 2005.
- [17] A. Drachen, R. Sifa, C. Bauckhage, and C. Thureau, "Guns, swords and data: Clustering of player behavior in computer games in the wild," in *2012 IEEE conference on Computational Intelligence and Games (CIG)*, pp. 163–170, IEEE, 2012.
- [18] "Axie infinity economy booms as nft sales rise." <https://news.bitcoin.com/axie-infinity-economy-booms-as-nft-sales-rise/>.
- [19] A. Drachen, A. Canossa, and G. N. Yannakakis, "Player modeling using self-organization in tomb raider: Underworld," in *2009 IEEE symposium on computational intelligence and games*, pp. 1–8, IEEE, 2009.
- [20] S. Fan, T. Min, X. Wu, and C. Wei, "Towards understanding governance tokens in liquidity mining: a case study of decentralized exchanges," *World Wide Web*, pp. 1–20, 2022.
- [21] S. Fan, T. Min, X. Wu, and W. Cai, "Altruistic and profit-oriented: Making sense of roles in web3 community from airdrop perspective," in *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems*, pp. 1–16, 2023.