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Distributed Computing

Understanding the economies of blockchain games: an empirical analysis of Axie Infinity

Bachelor's Thesis

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Abstract

Gamers pay game studios for the entertainment value of playing their games. This longstanding understanding of gaming has been challenged by the "play-to-earn" (P2E) concept, which has attracted criticism, with many questioning this new model's economic viability and long-term sustainability. GameFi, which combines the concept of blockchain and P2E, seeks to offer real world economic incentives to players via cryptocurrencies. In our research, we developed a methodology to perform analytical studies of the economy of Axie Infinity, the most prominent game in the GameFi category. We developed a solution for collecting smart contract logs and introduced a processing pipeline to refine the logs, which enables us to demonstrate how diverse metrics are applied to this data to gather insights into the game's economy. We explored and analyzed the data to find patterns that could indicate the presence of imbalances and anomalies, and other interesting properties of the game's economy. For example, we found that the top 1% and 0.1% of wallets earned more that two-thirds and one-half respectively of the real world earnings from Axie Infinity.

Contents

Chapter 1

Introduction

As blockchains entered into mainstream conversation, traditional gaming has also become a target of this revolutionary technology. This led to the emergence of GameFi, collectively referring to a category of games built on decentralized systems, which seek to offer real world economic incentives to players.

This concept of "play-to-earn" (P2E) represents a disruption to the incumbent understanding of gaming, based on the following agreement: *gamers pay game studios for the entertainment value of playing their games.* This significant paradigm shift has naturally attracted criticism, with many questioning P2E model's economic viability and long-term sustainability.

Axie Infinity [1], as the most popular "play-to-earn" game, has been the flag bearer of this new movement within gaming. As such, it has attracted the lion's share of criticism, with detractors questioning the financial assumptions of the payment model [2, 3], and the future lifespan of the game [4]. With many of the players coming from low-income South Asian countries [5], many of whom came to rely on the game as a main source of income [6], critics speculate on the effects that fluctuations in earning potential may have on the longevity of the game.

These economical viability concerns about GameFi are exacerbated by a extensive history of fraudulent activities during the relatively short existence of blockchains technology [7]. There have been several instances of fraud on all the major blockchains, ranging from Ponzi schemes to pump-and-dumps, which has attracted academic interest in the study and detection of these financial crimes [7, 8].

Motivated by these two concerns, namely the P2E economical model's viability and vulnerabilities of the underlying blockchain technology, we seek to understand whether we can apply traditional economic models to the study of a blockchain based game, and whether this can give us insights into the properties of the economy of Axie Infinity. We ultimately seek to detect anomalies in the financial system of the game, which could potentially demonstrate a kernel of truth in the issues raised by critics regarding the economical viability of P2E games such as GameFi.

In this thesis we develop a methodology to perform analytical studies of the economy of Axie Infinity. We aimed at understanding whether data collected from the game's transaction history can be used to understand characteristics of the game's financial system. Therefore, our methodology can be extended and applied to study the financial system of other games or other (decentralised) applications. Firstly, we design and develop an approach to collect data about transactions that take place within Axie Infinity. This involves understanding the characteristics of the smart contracts that power the game and how this changes over time, thereby providing us with a full transaction history for the game. Secondly, we apply our approach to process the raw data enabling us to gain valuable insights into the properties of in-game economy, such as the structure of contract logs. We subsequently develop a processing pipeline to efficiently manage inputs from previous steps. Finally, we analyse the data to find patterns that could indicate the presence of imbalances and anomalies within the economy of the game. To demonstrate the effectiveness of our methodology, we develop various metrics and apply them to the data we have collected. For instance, we observe large variances in pay-offs between players, indicating a large inequality in real world earnings. More specifically, we found that the top 1% and the top 0.1% wallets were responsible for more that two-thirds and one-half respectively of real world earnings from Axie Infinity.

Since the phenomenon of GameFi and a disruptive blockchain technology is rather recent, there are several gaps in the research needed to develop analytical methods to systematically answer open questions and evaluate risk scenarios such as financial viability of a P2E platform. More specifically, this thesis's main contributions pertain to answering the following research questions:

1. Determine which economic measures we can apply to the study of Axie Infinity; how to best adapt them to the available data and which assumptions are necessary to do so.

2. Explore patterns in the data and discuss whether they can be used to ascertain the viability of the game and the safety for potential players

3. Review the findings and propose how this approach can be extended to the study of other games or blockchain applications

The outline of the thesis is as follows: chapter 2 provides details of Axie Infinity. This will be followed by the related research in this field in section 3.1. Section 3.2 describes the background related to the online gaming platforms and their economics. The methodology is introduced in chapter 4 with a comparison of advantages and shortcoming with the existing work. Key findings are presented in chapter 5 followed by the conclusions and ideas for future work in chapter 6.

CHAPTER 2

Axie Infinity

This chapter describes the key terminologies, concepts and mechanisms of Axie Infinity.

Axie Infinity is an online video game developed by Vietnamese game studio Sky Mavis. Players build a team of digital pets called Axies, which they then use to battle against computer opponents or against other online players. Additionally, players can breed, raise and sell their Axies in an in-game marketplace.

2.1 Inner mechanisms

In traditional online games, data relating to asset ownership is stored in private databases and the code powering transactions between parties is kept hidden by the developers. Blockchain games seek to replace these with the blockchain itself and smart contracts respectively. However, in practice, there typically are elements of the game that remain outside the blockchain, referred to as “off-chain”. In the case of Axie Infinity, examples of these off-chain data are information about battles (both player-versus-player and player-versus-environment), the characteristics of Axie and the details of their breeding. On the other hand, any transaction of any token (including unique ones, such as Axie) in Axie Infinity is powered by the game’s smart contracts and are thus visible on the game’s blockchain.

Furthermore, the developers of these games typically make the smart contracts (that handle the execution of transactions) open source[1].

In Axie Infinity there are 25 smart contracts run the back-end of the game, listed in table 2.1. They handle all the transactions in the game. Out of the 25 contracts, only a few are useful for our purposes of studying the game. A brief description of these key smart contracts:

- Various smart contracts relating to in-game currencies. For example, the *Smooth Love Potion Contract* handles any transfer of SLP, be it between

[1] This is not the case for Ronin, which is also more "centralised" that the typical blockchain (more on this in section 2.2).

players or between the game and players (as part of rewards claimed for successfully playing the game). Smart contracts relating to the other in-game currencies (such as RON, WETH, AXS, etc.) function analogously.

- The *Ronin Gateway Contract*, which is the Ronin side of the bridge.
- The *Marketplace Contract* processes sales on the in-game marketplace. This involves actions such as the creation of auctions and the processing the transfer of funds after a successful sale.

Table 2.1: Contract name and address of the 25 smart contracts that power Axie Infinity.

Smart contract name	**Contract address**
Ronin WETH Contract	0xc99a6a985ed2cac1ef41640596c5a5f9f4e19ef5
Axie Infinity Shard Contract	0x97a9107c1793bc407d6f527b77e7fff4d812bece
Smooth Love Potion Contract	0xa8754b9fa15fc18bb59458815510e40a12cd2014
Axie Egg Coin Contract	0x173a2d4fa585a63acd02c107d57f932be0a71bcc
USD Coin Contract	0x0b7007c13325c48911f73a2dad5fa5dcbf808adc
Wrapped RON Contract	0xe514d9deb7966c8be0ca922de8a064264ea6bcd4
Axie Contract	0x32950db2a7164ae833121501c797d79e7b79d74c
Land Contract	0x8c811e3c958e190f5ec15fb376533a3398620500
Land Item Contract	0xa96660f0e4a3e9bc7388925d245a6d4d79e21259
Exchange Contract	0x2da06d60bd413bcbb6586430857433bd9d3a4be4
Marketplace Contract	0x213073989821f738a7ba3520c3d31a1f9ad31bbd
Offer Auction Contract	0x5b16d12a0c2c88db94115968abd7afa78b6bc504
Katana Factory Contract	0xb255d6a720bb7c39fee173ce22113397119cb930
Katana Router Contract	0x7d0556d55ca1a92708681e2e231733ebd922597d
AXS-WETH LP Contract	0xc6344bc1604fcab1a5aad712d766796e2b7a70b9
SLP-WETH LP Contract	0x306a28279d04a47468ed83d55088d0dcd1369294
USDC-WETH LP Contract	0xa7964991f339668107e2b6a6f6b8e8b74aa9d017
RON-WETH LP Contract	0x2ecb08f87f075b5769fe543d0e52e40140575ea7
Staking Manager Contract	0x8bd81a19420bad681b7bfc20e703ebd8e253782d
AXS Staking Pool Contract	0x05b0bb3c1c320b280501b86706c3551995bc8571
AXS-WETH LP Staking Pool Contract	0x487671acdea3745b6dac3ae8d1757b44a04bfe8a
SLP-WETH LP Staking Pool Contract	0xd4640c26c1a31cd632d8ae1a96fe5ac135d1eb52
RON-WETH LP Staking Pool Contract	0xb9072cec557528f81dd25dc474d4d69564956e1e
Ronin Gateway Contract	0xe35d62ebe18413d96ca2a2f7cf215bb21a406b4b
Ronin Validator Contract	0x0000000000000000000000000000000000000011

As the Ronin blockchain is only accessible to trusted nodes (i.e. is effectively kept private from third-parties), it is not possible to query the balance of a wallet or monitor transactions between two parties by directly downloading the blockchain; this would work for public blockchains like Bitcoin or Ethereum, as, by definition, the blockchain is simply a ahared list of all transactions that have taken place (and been included in a validated block). Sky Mavis does host the website Ronin Chain Explorer[2], where one can see all the data that would normally be available to any other public blockchain. For example, it is possible to see:

- The tokens (both ERC-20 and ERC-721) in a given wallet
- The transactions that have taken place between any wallets
- The logs of any of the 25 smart contracts that power transactions

There is however data that remains off-chain in Axie Infinity, i.e. inaccessible to even via block explorers. Some examples of this are the history and outcomes of Axie battles and the traits of Axies (see section 2.3).

2.2 Ronin

Axie Infinity is a blockchain game: instead of running on a centralised database operated by a game developer, it runs on a distributed blockchain network. The game originally ran directly on the Ethereum blockchain, but as the game grew, issues relating to congestion and GAS prices became a significant bottleneck. Axie Infinity has since move on to Ronin, Sky Mavis' Ethereum sidechain.

As opposed to the traditional proof-of-work sidechains, such as Ethereum or Bitcoin (where miners solve hashing problems to validate the next block), Ronin relies on a proof-of-authority system. This essentially "recentralises" the blockchain, as validators here are trusted parties operated by Sky Mavis. It is no longer necessary to expend resources verifying that nodes are who they claim to be, which is a the core of the expensive computations involved in blockchains. The advantages of this approach are linked to speed and cost - any game based on Ethereum's main network would be plagued by issues relating to long delays and expensive GAS prices. These savings are transmitted to the players of Axie Infinity: there are no transaction fees to contend with.

2.3 Axies

Axies are unique ERC-721 tokens, each one having distinct features or "genes". Each Axie belongs to a class of body shapes and consists of 6 body parts. These parts possess 3 genes: dominant (D), recessive recessive (R1), and minor recessive (R2). See the bottom right of figure 2.1 for examples of some of these traits.

[2] https://explorer.roninchain.com/

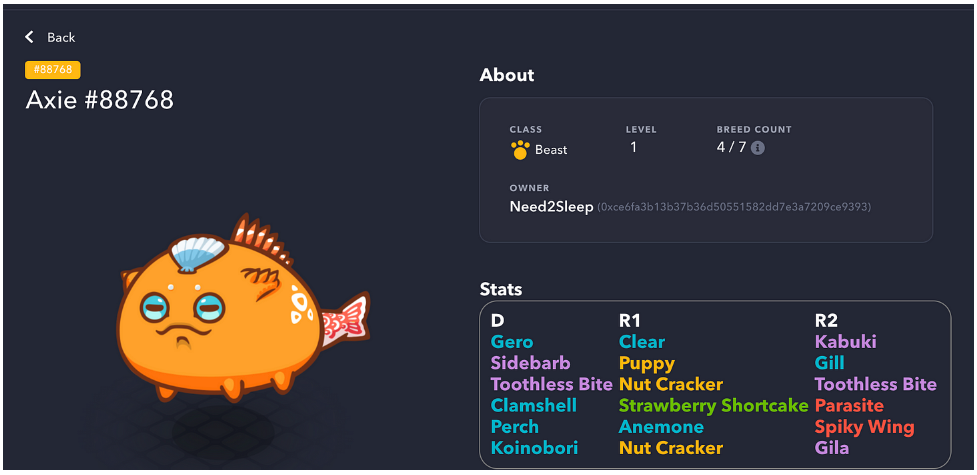

Figure 2.1: The characteristics of an Axie

Axies can be bred to produce offspring Axies, whose genetics are determined by a process based on Mendelian inheritance.

To restrict the supply of Axies, there is a mechanism in place that limits the number of times an Axie can be bred.

2.4 Gameplay

The gameplay of Axie Infinity resembles that of turn-based card games, similar to that of the popular game Hearthstone. Teams of 3 Axies (Axies are the cards) battle one another, with each side trying to eliminate the enemy Axies. This involves knowing the battle characteristics of each Axie, composing a complementary team, and strategically playing the moves that maximize the chance of victory.

There are two game modes in Axie Infinity: player-versus-environment (PvE) and player-versus-player (PvP).

In PvE, otherwise known as Adventure Mode, players battle computer-controlled teams of Axies and fight to win Smooth Love Potion (SLP). With 36 levels of increasing difficulty, the game's PvE opponents progress to match the level of the player.

For more advanced players, the game features a PvP Arena mode. This is identical the PvE mode, except the opponent here is another human playing the game. To reward the players for the increased difficulty, the payoffs of SLP can be much greater for Arena mode.

Figure 2.2: A battle between two teams of Axies

2.5 Tokenomics of Axie Infinity

Axie Infinity is a "play-to-earn" game, a type of video games that seeks to reward players for their effort with tokens that have real monetary value. This category of game is referred to collectively as GameFi. In the case of Axie Infinity, winning players are rewarded with Smooth Love Potion, an ERC-20 token that players can trade for real world money.

Within Axie Infinity, there are a variety of native ERC-20 tokens, the primary ones being:

- Smooth Love Potion (SLP), rewarded to players for their achievements and used to breed Axies
- Axie Infinity Shards (AXS), the governance token of the Axie Universe
- Ronin Wrapped Ether (WETH or ETH), the currency used on the Axie Marketplace to buy and sell Axies

For players who hold other cryptocurrencies and wish to convert them to an Axie Infinity currency, the main approach is to use the Ronin Blockchain bridge. Bridges are present between many blockchains, and are designed to allow interoperability between isolated blockchains. They function via smart contracts, and work by "locking" a certain amount of the native currency of the source blockchain (so it cannot be used, thus avoiding doubling - tokens that exist both on source and destination blockchains). The exchanger is then given a wrapped version of that original currency that is usable on the destination blockchain. In

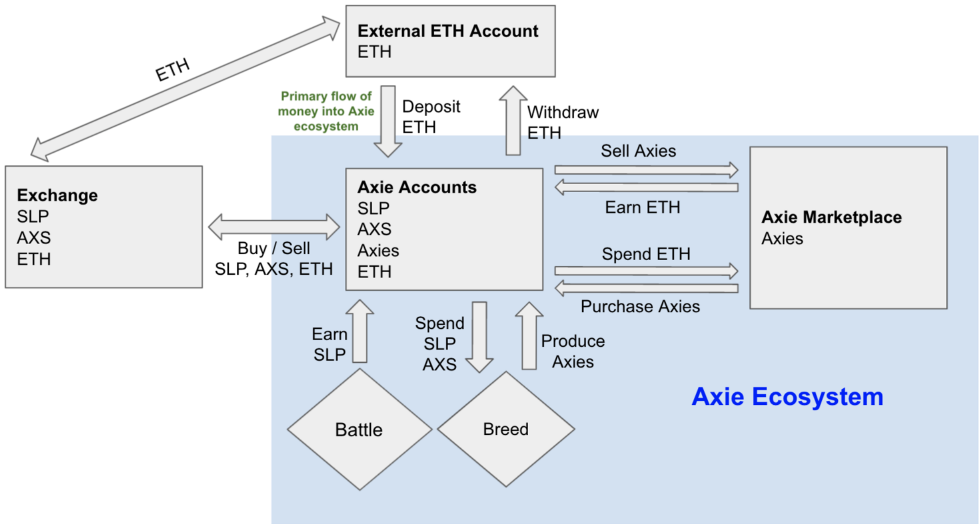

Figure 2.3: A flow chart of the various Axie Infinity tokens. Source: Axie Infinity whitepaper [1]

the example of Axie Infinity, a player holding Ether could exchange this via the smart contract and have one Ronin Wrapped Ether (WETH) deposited in their Ronin Wallet.

Additionally, there are exchanges that support buying and selling of Axie Infinity tokens directly with real world money. The largest such exchange is Binance, who offers purchases of Smooth Love Potion in exchange for 6 other mainstream cryptocurrencies.

As a traditional finance analogy, one could think of Eurodollars, i.e. dollars held in bank outside the United States.

Chapter 3

Related work and background

This chapter presents 3 key areas of related work to the topic of this paper. Additionally, we present brief background of the history of blockchain gaming alongside a catalogue of notable games, comparing these to Axie Infinity.

3.1 Related work

We look into different dimensions of the related work. Firstly, an overview behaviour of players in virtual economies is presented. Work in this area has profited from games with large online communities, using their in-game marketplaces as a starting point for comparisons with real-world economies. Researchers have looked into the social and financial factors that draw players to these games. Secondly, a review of fraud detection on blockchains is provided. Both on the Bitcoin and Ethereum blockchains, researchers apply machine learning to recognise patterns of nefarious activity. Finally, we touch on research that has explored early "play-to-earn" behaviour in traditional (as opposed to blockchain) games. Beginning with the initial causes that inspired this demand for virtual goods (in exchange for real money), researchers describe the birth of a new market around virtual goods and its progression into an industry organised along traditional corporate lines.

Player behaviour in virtual economies

With the emergence of *massively*-multiplayer online games and their large player bases, research has been done into the social and economic factors that drive players to invest time into the games. More specifically to the scope of this work, the large in-game marketplaces have become a target of academic interest. Research has been done into the aggregate behaviours of these complex economies, seeking comparisons with real-world financial systems via the application of traditional economic models. Furthermore, researchers have explored the real-world monetary incentives that motivate certain groups of players.

Castronova [9] offers a first-hand account of his time playing in the virtual world of Norrath, the setting of the popular online game Everquest. He seeks to engage with other gamers, observe in-game behaviour and understand the financial factors that drive players to dedicate long hours to the game. He concludes by proposing an approach to quantifying the real world value of in-game rewards and explaining the assumptions this estimation presupposes. Drawing inspiration from this work, Heeks [10] studies the real world economic factors that drive the phenomenon of *gold farming*, i.e. players (typically in low-income South Asian countries) performing in-game tasks with the final purpose of selling the rewards to other players (for real money) to generate an income.

In later work [11], Castronova applies traditional economic measures to the in-game economy of Everquest 2, the sequel to Everquest. Here he adapts standard economic definitions to virtual worlds and tests classical macroeconomic theories within the markets of Everquest 2. More specifically, he applied the notions of gross domestic product and the quantity theory of money[1] to the game's economy, seeking similarities between real and virtual worlds.

Additionally, work has been done into the social factors that influence real money spending in online games [12], demonstrating that gifts of virtual goods between players can be a strong source of income for game studios. Research into the dynamics of online communities in games [13] can indicate to developers design decisions that maximise group cohesion, which strongly predicts gifting behaviour [12] and could serve to maximise profits for the studios. For example, research [12] has indicated the importance of "design for the spectator experience", namely design decisions that favour situations where players can see and be seen by other players, thus imbuing the virtual goods with value within a social hierarchy.

Fraud detection on blockchain

The prevalence of fraudulent activity on the blockchain has attracted academic interest, particularly aimed at the detection and prevention of these crimes. Researchers in this area have leverage machine learning to try to automate process of detection. This work has experimented with several approaches; various features of the blockchain have been used as input for these models, from the transaction history of a wallet address to the byte code of a smart contract.

The prevalence of fraudulent activity on the blockchain has attracted academic interest, particularly aimed at the detection and prevention of these crimes. Bartoletti *et al.* [7] experimented with fraud detection via machine learning mod-

[1] From [11]:"The quantity theory of money (QTM) is a basic theory of motion using these measures along with population and stability. It states that under simple conditions, the price level is proportional to the ratio of money in the system and to the amount of goods being traded."

els trained on the transaction history of Bitcoin wallets. Using a dataset partially comprised of wallets associated in past Ponzi schemes, they show the effectiveness of various models and approaches to managing imbalanced classifications in this context.

The same authors also performed a survey of Ponzi schemes taking place on Ethereum [8], which demonstrated a high prevalence of such scams taking place during the short lifetime of the blockchain. Additionally, Shen *et al.* [14] demonstrated how machine leaning can be used to detect Ponzi schemes running on Ethereum smart contracts. The input data for these models is the byte code generated from these contracts, which run on the Ethereum Virtual Machine (EVM).

Early uses of money in games

Academic work has been undertaken to understand the exchange of real money for virtual goods in games, a phenomenon dating back more than 40 years. Researchers seek to understand the supply-and-demand conditions of the games that created this market and the economic realities than drove its growth. As is the case with Axie Infinity, emerging South Asian economies play a key role in this history, with players here eager to provide the supply side of this exchange. We later see these players forming groups that mirror the organisation of traditional companies to more easily gather virtual goods to sell, motivated by efficiency and economies of scale.

Examples of *real money trading* (RMT), the trading of virtual world items, currencies and service for real money date back to at least 1987 [10].

Only later did the practice of *gold farming* take hold: now players of the game completed (typically repetitive) tasks to earn in-game rewards with the final purpose of selling them to other players, in exchange for real world money. The games involved are typically massively multiplayer online role-playing games, or MMORPGs, which generally involve periods of "grinding" for players to advance in the game. This entails repeating monotonous quests for an extended period of time.

It is suspected that the 1997 Asian currency crisis played a pivotal role in creating the phenomenon of gold farming: many newly unemployed players took to PC kiosks to find a new source of income [10]. Players in wealthier (mostly Western) countries were apt to exchange real money to avoid the tedium involved with collecting these virtual goods themselves.

A whole industry quickly sprouted up around this market, as third-party website were established with the purpose of facilitating trades [11]. Additionally, *gold farms* came into existence: players organised into hierarchical groups that mirrored the structure of a traditional company, with the purpose of generating in-game assets more efficiently [10].

Since the phenomenon of GameFi and a disruptive blockchain technology is rather recent, there are several gaps in the research needed to develop analytical methods to systematically answer open questions and evaluate risk scenarios, such as the financial viability of a P2E platform. Existing reasearch in blockchain gaming is limited to high-level discussions [15, 16, 17] of its advantages and disadvantages (compared to traditional online gaming) and investigations into the security of the underlying blockchain technology [18]. This paper's main contributions pertain to extending existing research in traditional online game economies to blockchain gaming. We accomplish this by determining which economic measures can be applied to Axie Infinity and presenting the adaptations and assumptions this entails. Furthermore, we explore patterns in the data and discuss whether they can be used to ascertain the viability of the game and the safety for potential players.

3.2 History of blockchain gaming

To better understand the context surrounding Axie Infinity, we undertook a study of the blockchain game ecosystem. My sources for this undertaking were the websites of the projects themselves. The findings are in table 3.2, along with an explanation of the properties we used to understand the significant differences between the games.

As the table shows, early blockchain games were all gambling schemes: these games were traditional casino games implemented in smart contracts. Compared to later GameFi projects (such as Axie Infinity), these games were primitive from a technical standpoint: they used existing cryptocurrencies (as opposed to native currencies such as SLP or AXS), were running on layer 1 blockchains, and often had no UI. Furthermore, they lacked "deep" game elements, such as in-game marketplaces and unique player-owned assets.

Over time, these games grew more sophisicated. Moving past the gambling space, there emerged more complex strategy, sandbox and metaverse (an emergent category) of blockchain games. With the dramatic growth of the non-fungible token (NFT) market in recent years, blockchain games came to include them. This provided game developers with a way to issue players unique in-game assets. Parallel to this development, more advanced in-game economies enabled players to trade with one another.

As we can see from the Table 3.2, Axie Infinity is among the most technically intricate games, with features such as:

- A variety of native in-game currencies: SLP, AXS and others.
- Axies, unique in-game assets

- A complex player-to-player marketplace within the game

Furthermore, Axie Infinity is the only game to make use of its own blockchain, Ronin. Although Ronin is a layer 2 clone of the Ethereum blockchain (i.e. it is built on Ethereum), the ownership of this blockchain allowed Sky Mavis to design the network to best suit the needs of the playerbase (e.g. choosing proof-of-work vs. proof-of-authority).

Game name	Blockchain	Game type	Release date	In-game currency	In-game assets (NFTs)	Asset ownership	In-game economy
Satoshi Dice	Bitcoin	Lottery/Gambling	4/2012	No	No	No	No
PoWH 3D	Ethereum	Lottery/Gambling	2/2018	Yes	No	No	No
Fomo 3D	Ethereum	Lottery/Gambling	7/2018	No	No	No	No
BetDice	EOS	Lottery/Gambling	9/2018	No	No	No	No
FarmEOS	EOS	Lottery/Gambling	10/2018	No	No	No	No
TRONBet	Tron	Lottery/Gambling	10/2018	Yes	No	No	No
CryptoKitties	Ethereum	Virtual pet	11/2017	No	Virtual cats	Yes	Yes
Etheremon	Ethereum	Strategy game	12/2017	No	Pokemon	Yes	No
EtherGoo	Ethereum	Idle game	4/2018	No	Yes	Yes	No
TronGoo	Tron	Idle game	1/2019	No	Yes	Yes	No
Gods Unchained	Ethereum	Trading card game	7/2018	No	Yes	Yes	Yes
0xUniverse	Ethereum	Strategy game	7/2018	No	Yes	Yes	No
EOSKnights	EOS	Strategy game	8/2018	Yes	Yes	Yes	Yes
EOSDOTA	EOS	Trading card game	1/2019	No	Yes	Yes	Yes
HyperSnakes	Ethereum	TRON	PvP	5/2019	No	Yes	Yes
KittyRace	Ethereum	Racing sim	3/2018	No	Yes	Yes	No
KittyBattle	Ethereum	Turn-based PvP	12/2018	No	Yes	Yes	No
KotoWars	Ethereum	Strategy game	12/2018	No	Yes	Yes	No
Cell Evolution	Nebulas	Strategy game	5/2018	No	No	No	No
Crypto Space Commander	Ethereum	Sandbox MMO	4/2019	No	Yes	Yes	Yes
Axie Infinity	Ronin	Strategy game	3/2018	SLP, AXS, etc.	Axies (digital pets)	No	Yes
Sorare	Ethereum	Sports game	12/2018	No	Football cards	Yes	Yes
Decentraland	Ethereum	Metaverse	02/2020	MANA	Plots of land	Yes	Yes
The Sandbox	Ethereum	Metaverse	11/2021	Yes	Plots of land	Yes	Yes

Table 3.1:

In-game currency: whether or not the game has a cryptocurrency native to the game

In-game assets: the game supports unique in-game tokens, also referred to as NFTs (typically an ERC-721 token).

Asset ownership: the assets can be removed from the game to a player's wallet

In-game economy: the game has a in-game marketplace that supports player-to-player trades

Chapter 4

Methodology

This chapter explains the data collection and analysis methodology that was developed, including details on challenges for data gathering, insights into a smart contract log and the processing pipeline. Additionally, we motivate our decision to work with Binance trade data and the process this entailed. The collection of these two sets of data constitute the "data mining" stage of our project.

4.1 Approach to data collection

Smart contract logs

Collecting data on player behavior or transactions within traditional online games has often been hindered by restrictions placed by game companies. The reasons cited are desire to reduce the likelihood of fraud and exploitation [11]. Companies are also often unwilling to share the data that they do collect, with the intention of protecting their business practices and proprietary information [10, 11].

One would imagine that this issue does not concern games based on a blockchain, as by definition (traditionally) a blockchain a publicly available ledger. This would imply that anyone who is willing to establish a node could gain access to the full history of transactions. This, however, is not the case for Axie Infinity: the game takes place on a centralized blockchain, whose validators are only internal nodes owned by Sky Mavis (the game studio that owns Axie Infinity).

Sky Mavis maintains the Ronin Chain Explorer[1], a block explorer for the Ronin blockchain. Here, anyone can (for example) view the transactions associated with a certain wallet address or check ownership of an Axie. Sky Mavis place technical limitations on data that can be obtained from the website (e.g. it is only possible to see most recent 10'000 transactions for any account, including smart contracts), so it is clear that this website is not intended for the purposes of large-scale data analysis.

[1] https://explorer.roninchain.com

Sky Mavis partnered with Covalent, a company that provides an API (primarily for developers and analysts) that allows indexing and accessing events on the blockchain. Some examples of queries supported by this API are getting transactions associated with the given wallet, monitoring the price of an NFT or getting the latest block height of a given blockchain. By extending the use of the API to the Ronin blockchain, this service provides the same functions as the Ronin Chain Explorer, without any of the limitations. In this way one can obtain a full history of the blockchain.

Binance trade data

As previously mentioned, another method for withdrawing tokens from Ronin is by using an exchange. This works as follows: first, a player sends their Ronin token (SLP, AXS, etc.) to a wallet (on Ronin) owned by the exchange; then, they receive payment (which can be another non-Ronin cryptocurrency or FIAT depending on user preference and the exchange) to their external wallet or exchange account.

The process for using an exchange to deposit to Ronin with non-Ronin tokens is the aforementioned process, simply reversed.

To determine how much SLP was being withdrawn via these exchanges and if we could find large inequalities among players in terms of earnings (as had been the case for the Ronin Bridge in section 5.2), we decided to concentrate on the largest exchange that supports SLP withdrawals, namely Binance.

One way to trace the SLP that is being exchanged from Ronin from Binance would be to determine which Ronin wallet addresses belong to the exchange. Unfortunately, there is no way to know which addresses belong to whom. This is in contrast with Ethereum, where there are block explorers (such as Etherscan[2]) that let wallet owners or third parties "flag" the real owner of an account. Furthermore, it could be the case that an exchange operates multiple addresses on a blockchain (as is the case with Binance on Ethereum) and divides the activity between them.

It is possible to understand the volume of SLP being exchanged via Binance by using data from the Binance Data Collection[3], which is historical market data from Binance that the exchange makes publicly available (via direct download or API). Binance supports 6 pairs which have SLP as the source cryptocurrency[4].

[2]https://etherscan.io/

[3]https://data.binance.vision/

[4]These pairs are SLP-BIDR, SLP-BNB, SLP-BUSD, SLP-ETH, SLP-TRY, SLP-USDT. In other words, SLP can be traded for Binance Chain stablecoin, BNB coin, Binance USD stablecoin, Ether, Try.Finance coin or Tether respectively.

Conversion to real-world currency

In cases where it was useful to know the dollar amount of the tokens we were studying, Yahoo Finance[5] was used as a source for the SLP-USD or ETH-USD historical prices. As the price of a token could fluctuate (significantly) during the course of a day, we always provide an higher and lower estimate for that metrics (to reflect the daily high and low price).

4.1.1 Data collection

For the purposes of this project, we used the Covalent API to get the logs of the 25 smart contracts that power the game (as discussed in chapter 2.1). The API offers a query that exactly suits this purpose, namely one that returns the contract logs for a given contract address (within a certain block range).

We wrote a script that utilised the aforementioned query to collect the logs of all contracts between the first block and the 12 millionth block (chosen arbitrarily as it happened to have been validated on the 18th of March 2022, roughly when this project began).

An issue encountered at this stage was related to the large variance in numbers of transactions associated with a given contract. On one hand, there were smart contracts which were involved in only 11 transactions, like the one involved with managing the admin rights of other smart contracts; there were also contracts which had more than 100 million log event (e.g. the contract for Smooth Love Potion or the marketplace). The problem here was, that if the quantity of data involved in a query in a given block range was too large, the API would fail to return anything. Solving this involved breaking up a query into smaller parts. In other words, we reduced the size of the block range in the query for the more active contracts.

Downloading the trade history from Binance Data Collection proved straightforward. It was simply necessary to download the logs of trades from the same time period we considered in the previous paragraphs, which was be done directly from their website via a browser. The same was true for the price data from Yahoo Finance, which could be downloaded as a CSV directly from this website.

[5] https://finance.yahoo.com/

4.2 Approach to data analysis

4.2.1 A look at a smart contract log

Before delving into the details of the metrics studied, here is a brief explanation of what a smart contract log in Axie Infinity looks like. In figure 4.1 is an example of one transaction from the Smooth Love Potion smart contract logs, as seen on the Roninchain Explorer. The actual logs obtained in the "Data Mining" portion of this project have all the data seen in figure 4.1 (and more) in a less human-legible CSV format.

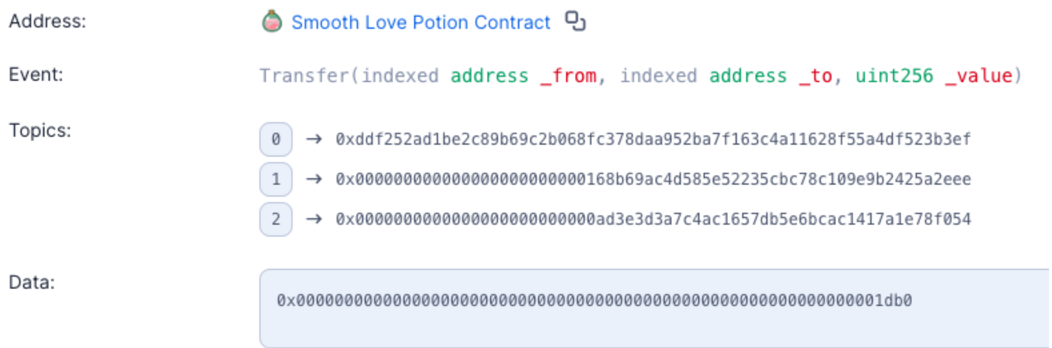

Figure 4.1: A transaction from the SLP contract log

While the details of logs vary between the 25 smart contracts in the game, they all have broadly the same structure (the following elements correspond the columns in the CSV log files):

- A parameter that indicates the type of log event it is. In the example above, this hexadecimal code (in the 0th position) indicates that this is a *Transfer* of SLP between two wallets (you can see this indicated after "Event:" too).
- Two parameters with the address sender and recipient of the transaction, in the first and second position respectively.
- The value of the transaction in hexadecimal format (here after "Data:"), corresponding to amount (in the case of in-game currencies) or the unique ID of an NFT (in the case of Axies) that was transferred.
- Other parameters, such as the hash of transaction, the height and signing time of the block which the transaction belongs to and many others.

4.2.2 Processing pipeline

The next step is to consider our approach to processing and manipulating the data. The scripts written to this end all had the same general structure:

1. Decompress the raw log CSVs, only reading in the necessary columns[6].
2. Filter based on log event. Here, we consider the type of event that is involved in the desired metric and drop any data outside of this scope. For example, suppose we want data pertaining to sales that have taken place via the Marketplace contract. We would then keep only rows with the *AuctionSuccessful* tag (or rather, its hexidecimal equivalent) in the event column, dropping everything else.
3. Filter based on wallet addresses involved. Fundamentally, every log event is a transaction, with a sender and recipient. Although it may seem counter-intuitive, nearly every metric we will present necessitated picking a single wallet address and dropping all log events which did not involve that address. An example would be considering only transactions destined for the address of the Ronin Bridge contract, as these would constitute withdrawls of tokens from the game
4. Process the data. For metrics that used data relating to time, the *block_signed_at* column was converted to use Python's datetime module for easier manipulation in the later stages. Hexidecimal values were transformed to decimal in cases where it would improve readability (e.g. the case of amounts of a cryptocurrency or the volume of sales).
5. Merging into a single log. Until this stage, the logs of the contract were still partitioned into block ranges (spanning either 100 thousand or 1 million blocks), just as they had been when they were downloaded via the Covalent API. Before any further manipulation was possible, it was necessary to unify all the remain data into a single CSV file. This was a quick process, as the a large portion of the initial raw log data had been filtered out by this stage in steps 2 and 3.
6. The final stage in this process was aggregation of the processed data into desired groups. The types of metrics considered in the later subsections can broadly be divided into two types: those grouped by wallet address (e.g. amount of SLP earned per wallet on average) and those that are partitioned by units of time (e.g. volume of daily sales on the Marketplace).

[6]Reading in the minimal amount of data was an essential step to successfully running the scripts. The CSVs of raw smart contract logs, which spanned a range of either 100 thousand or 1 million blocks (depending on the number of transactions associated with a given smart contract, which could vary greatly), could easily be more than 30 GB when decompressed.

Chapter 5

Findings

This chapter explains how the methodology that was developed enabled us to explore different metrics and scenarios. Firstly, we look into currency and markets to establish the market volume and how currency is generated and consumed. Secondly, we study the impact of different withdrawal methods and present our results, namely the Ronin bridge metrics and Binance trade data. Finally, we explore Axie prices in the marketplace and risk potential for Ponzi schemes.

5.1 Currency and markets

5.1.1 Market volume

Having understood how to process the raw data, we began our investigation into the economics of Axie Infinity. The first metrics considered were strongly inspired by what Castronova's papers [9, 11], which were essentially traditional macroeconomic statistics applied to a virtual world (e.g. gross domestic product, quantity theory of money, measurements of currency emission).

Using the logs of the Marketplace smart contract, we calculated the daily sales volume on the contract (see figures 5.1 and 5.2). The relevant log events carried the *AuctionSuccessful* tag. Additionally, we kept the data relating to the time of sale (necessary for aggregating by daily amount) and the final price (in WETH). Operating under Castronova's definition[1] of production in virtual

[1] "There are four major transaction types recorded in the economy log: item production, item consumption, merchant transactions and consignment trade. The first three categories are not true transactions in an economic sense because economic transactions only happen between real people; rather, these are cases of the production and consumption of goods. Nonetheless, these basic categories have large implications for the measurement of GDP. If a player uses the crafting system to create an item, as in category 1, that certainly seems to be production. Yet in the real-world application of GDP, a produced good is not counted until it is sold to someone. If a corn farmer grows and eats some of his/her corn, that corn does not count in GDP, even though it was produced and has value. In practice, GDP is the value of all goods produced and sold in an economy. Thus, an effort to test the mapping of GDP into the virtual requires a focus solely on goods that are sold from one player to another: i.e. genuine trade." Thus,

worlds[11], this corresponds to an estimation of the GDP of Axie Infinity.

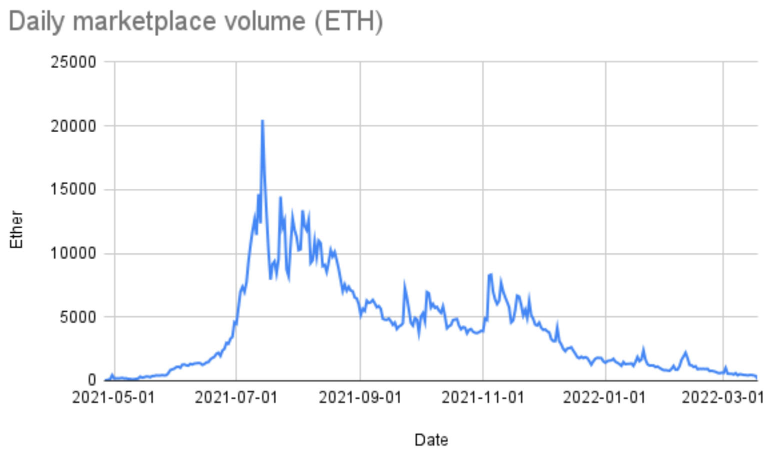

Figure 5.1: A graph of the amount of total Ethereum exchanged in the game's marketplace per day. The vertical and horizontal axes are the amount of Ethereum and date respectively.

As Castronova did his study of the virtual world of Norrath [9], we will now compare the GDP of Axie to that of a real country. Ignoring the fact that period studied is shorter than a year (by more than a month), the GDP of Axie would be between 3.9 and 4.2 billion dollars. This puts Axie Infinity at between Eswatini and Dijibouti in terms of national GDP[2]. The Roninchain Explorer reports that there are roughly 10 million unique wallet addresses. If we can entertain the idea that a wallet address corresponds to a real world citizen, this puts Axie Infinity's GDP per capita at about $420. By this metrics Axie Infinity would be one of the poorest countries in the world, above only South Sudan and Burundi[3].

5.1.2 Currency emission and destruction

As previously discussed, players earn Smooth Love Potion by using their Axies to battle. The two game modes are player-versus-player or player-versus-environment.

As with all transfers of SLP, a player claiming her rewards appears in the Smooth Potion Contract log as event with the *Transfer* tag. This particular instance of SLP exchange can be differentiated from normal player-to-player trans-

if we accept earned SLP as the harvest from completing quests within the game, marketplace volume corresponds to GDP.

[2] IMF estimate from 2022

[3] IMF esimate from 2022

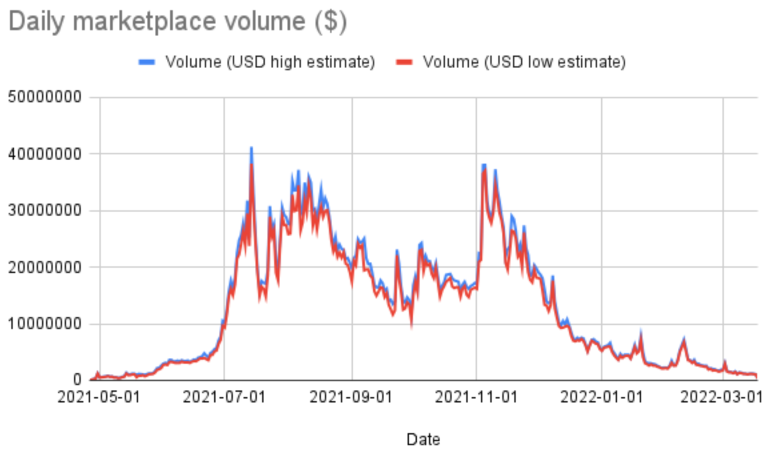

Figure 5.2: A graph of the amount of the USD value of Ethereum exchanged in the game's marketplace per day. The vertical and horizontal axes are this USD value and date respectively.

fers by the sender: in this case the sender is the null address[4]. Conversely, for SLP expended for breeding Axies, these transfers appear as SLP smart contract log events where the transfer recipient is the null address.

In this way we can make an analogy between the wallet of the null address and the central bank of a real country. Any SLP emitted by this wallet is effectively put into circulation, whereas any money sent to it is "burned". By changing the amount of SLP rewards for battling or the price of breeding, the developers of Axie Infinity effectively act as the economists of central banks deciding monetary policy. This analogy can be carried further, as the supply of SLP represented an important source of (real) income for many players. Changes in the game's reward mechanisms could have important implications for the group of players focused on the play-to-earn aspects of the game [19].

We next wanted to explore the currency emission and burning behaviour over time. To this end, using the approach outlined in section 4.2.2, we use Smooth Love Potion smart contract data to calculate the amount of SLP emitted and destroyed (i.e. sent and received by the null address respectively). The findings can be seen in figure 5.3.

This process also allows us to establish the number of daily active players: by determining the amount of (unique) wallet addresses that claimed SLP from battles during a given day. Similarly to the approach adopted in the previous paragraphs, we filter the SLP contract log data to keep only the date and address of the wallet claiming SLP. Then we aggregate by date, dropping any wallets that

[4]The address is a sequence of 40 zeros, i.e. 0x0000000000000000000000000000000000000000

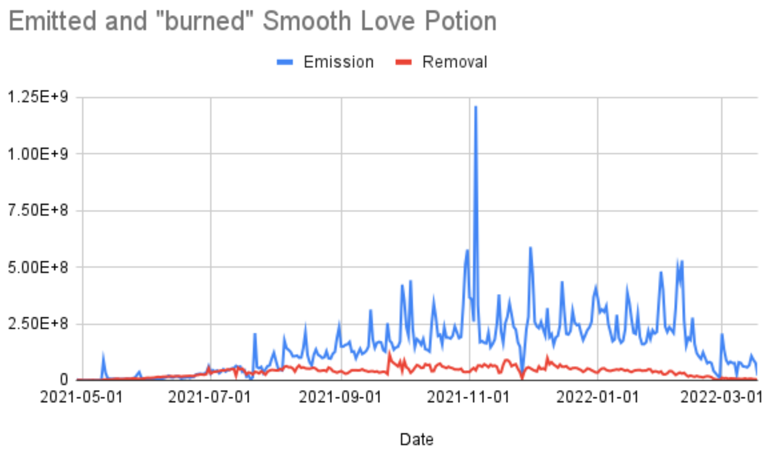

Figure 5.3: A graph of SLP currency statistics over time. The vertical and horizontal axes are the amounts of SLP and date respectively.

made multiple claims during the same date (to keep only once such instance, thereby guaranteeing uniqueness). The results are in figure 5.4. This method of estimating the size of the daily user base is interesting, as it actually reflects the number of people "playing" the game in the sense of battling with their Axies. This therefore excludes those idle wallets whose purpose may merely be vehicles for speculating on the price of Axie Infinity's in-game currency.

Having both the number of players and the SLP earned, we are now able to estimate the daily average earnings for a player of Axie Infinity. Due to relatively high earnings (both in terms of SLP and its USD value) in the first days of the game, we used a log scale in figure 5.5 and 5.6 to increase readiblility.

The results we find were suprising: the estimated daily earnings were consistently much higher than what we could have predicted, by a factor of up to 10. Our expectations were based on what we had read online about the earning potential from Axie Infinity for a (average) prospective player[5]. These findings gave us a premonition that would guide the later data analysis, namely that the payoffs from Axie Infinity were highly unequal. In other words, we theorize that there were a few players (wallet addresses) that were earning the lion's share of rewards from the game, with the majority getting a comparatively tiny share.

[5] https://naavik.co/deep-dives/axie-infinity

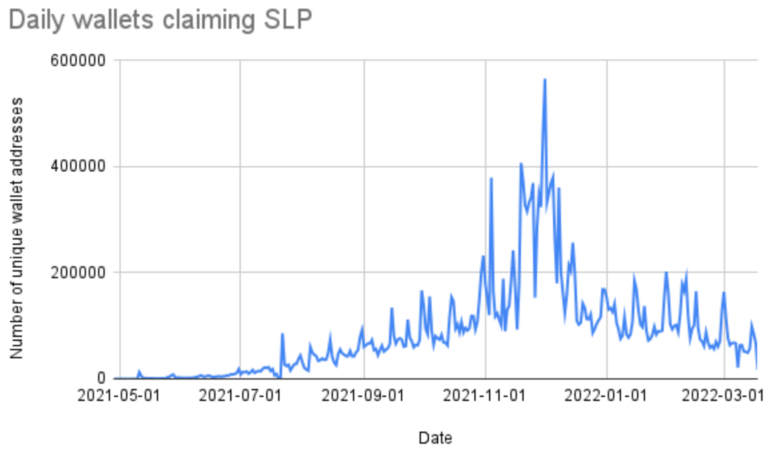

Figure 5.4: A graph of number of unique wallet addresses that claimed SLP per day. The vertical and horizontal axes are the amount of these wallets and date respectively.

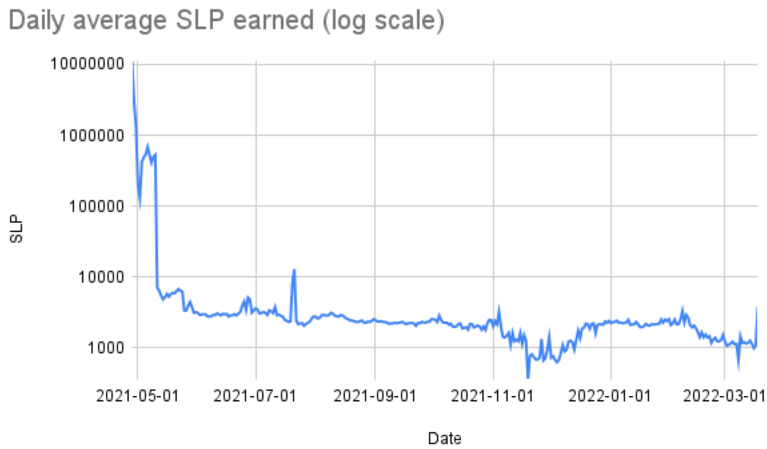

Figure 5.5: A graph of average amount of SLP earned by wallets per day. The vertical and horizontal axes are SLP (log scale) and date respectively.

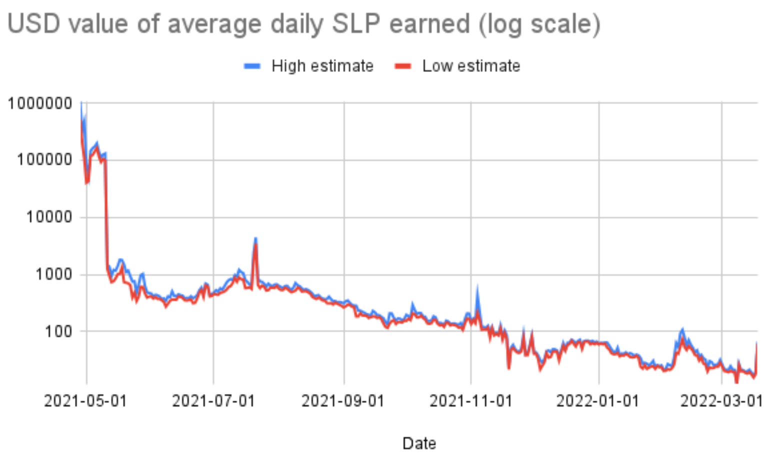

Figure 5.6: A graph of the dollar value of average amount of SLP earned by wallets per day. The vertical and horizontal axes are this dollars (log scale) and date respectively.

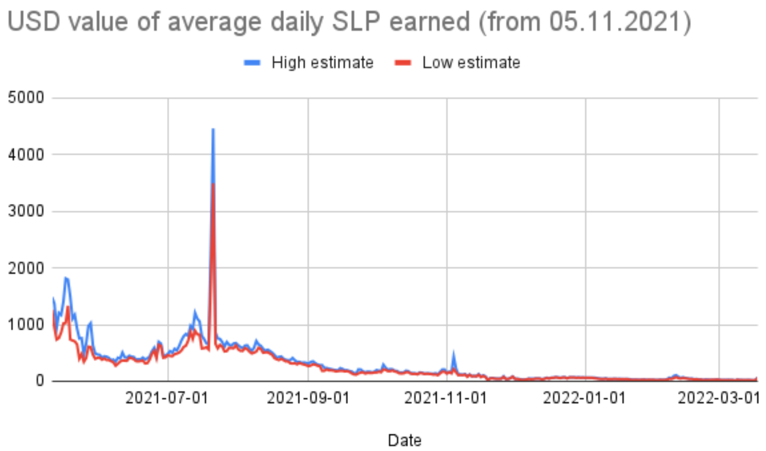

Figure 5.7: A graph of the dollar value of average amount of SLP earned by wallets per day, starting 7 days after the start date of figure 5.6. The vertical and horizontal axes are dollars (not logarithmic scale) and date respectively.

5.2 Ronin bridge metrics

There are multiple options for withdrawing earned tokens from the Ronin network. The most common way is the Ronin bridge (previously discussed in section 2.5), whereby players can transfer their SLP to their wallets on the Ethereum network. Additionally, Binance and a few other smaller exchanges support transfers of tokens from Ronin to Ethereum (and back again). We explore that approach in the next subsection.

We wanted to look into a bridge as a more precise way to measure the earnings of Axie Infinity players from SLP. While the daily claimed SLP gave an insight into how much a player *could* earn, now we could actually trace the real value of the tokens as they were withdrawn. This would cover cases where players would batch their "cash outs", i.e. players who earned SLP every day but only moved their tokens from Ronin to Ethereum infrequently. Since the value of SLP flucuates greatly over time (as is the case with many cryptocurrencies), the decision of when to remove tokens from Ronin could have a significant impact on earning potential.

We began working on the data from the Ronin Gateway smart contract, which is the Ronin side of the bridge. Following approach essentially identical to the previous section, we filtered the contract logs for transfers of SLP which had the address of the Gateway contract as the recipient. These correspond to outgoing movements of SLP. Then we aggregated these by day. See figures 5.8 and 5.9 for the results.

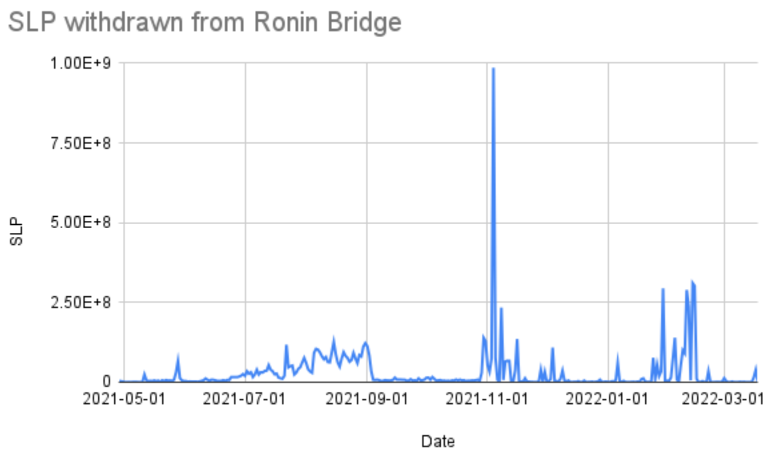

Figure 5.8: A graph of the amount of SLP exiting Ronin via the bridge per day. The vertical and horizontal axes are SLP and date respectively.

We had a chance to test the hypothesis we had developed in the previous sec-

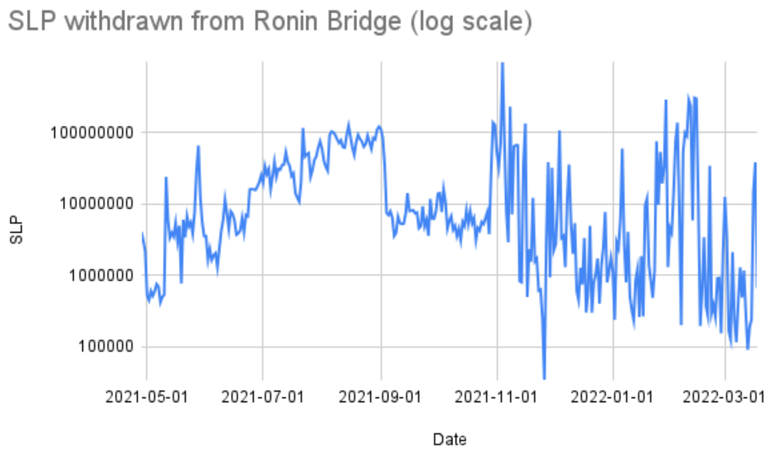

Figure 5.9: A graph of the amount of SLP exiting Ronin via the bridge per day, logarithmic scale. The vertical and horizontal axes are SLP (log scale) and date respectively.

tion. Namely, we wanted to see whether we could find any significant inequality in the amounts of SLP sent over the bridge on a per-wallet basis. This would allow us to determine how uneven the payoff between players is. We aggregated the SLP sent via the bridge by sender wallet address over the time period we studied. We looked at the earnings of the top 1 percent[6], comparing this amount to the rest of the players via in the pie chart in figure 5.10.

The results led to an interesting finding: the top 1 percent of SLP sending wallets sent more than two-thirds of the total SLP sent over the bridge. Spurred on by these findings, we repeated the previous approach with the top 0.1 percent[7]. Once again the findings were impressive: the top 0.1 percent wallets where responsible for withdrawing more than half of the total SLP. These findings can be seen in figure 5.11.

We present a histogram (figure 5.12) to better visualize the distribution of income (determined via withdrawals from the Ronin Bridge). As expected, the right skewness of the data necessitated a log histogram for readability.

5.3 Binance trade data

As previously mentioned, we downloaded all the Binance historical trade data for the 6 pairs with SLP as the incoming currency. We expected that the only

[6]The threshold for the top 1 percent was 255'768 SLP, i.e. a wallet would have to send (at least) this much SLP via the bridge during the study period to be in the top 1 percent.

[7]The threshold for the top 0.1 percent was 1'563'334 SLP.

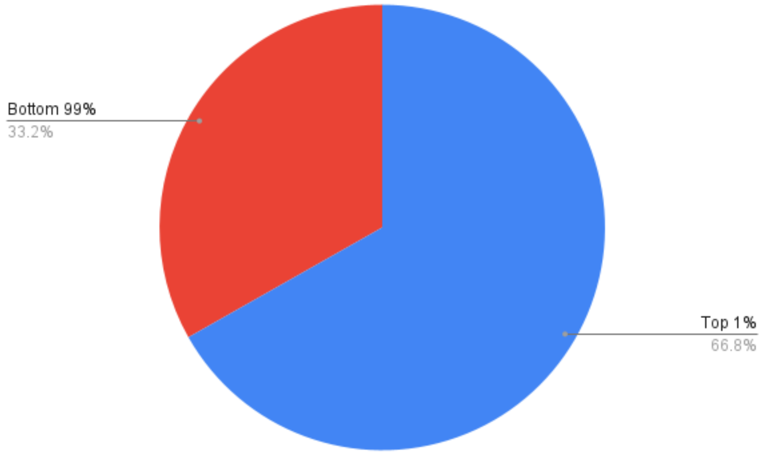

Figure 5.10: A pie chart comparing the amount of SLP withdrawn by the top 1% of wallets (in terms of amount withdrawn via the Ronin bridge) and the remaining 99%.

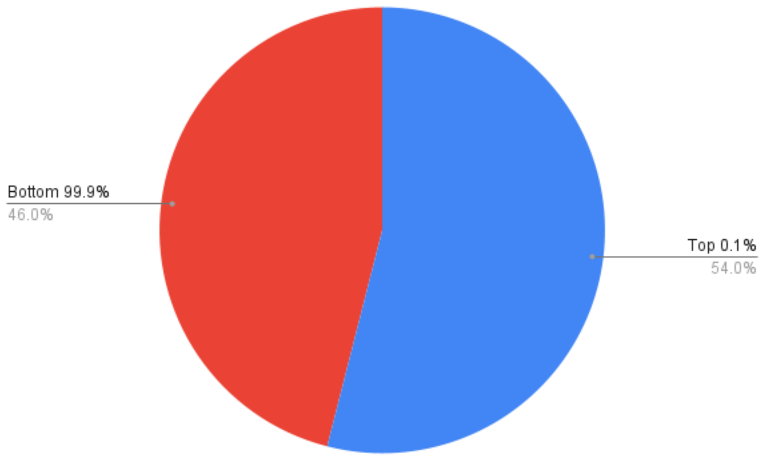

Figure 5.11: A pie chart comparing the amount of SLP withdrawn by the top 0.1% of wallets (in terms of amount withdrawn) and the remaining 99.9%.

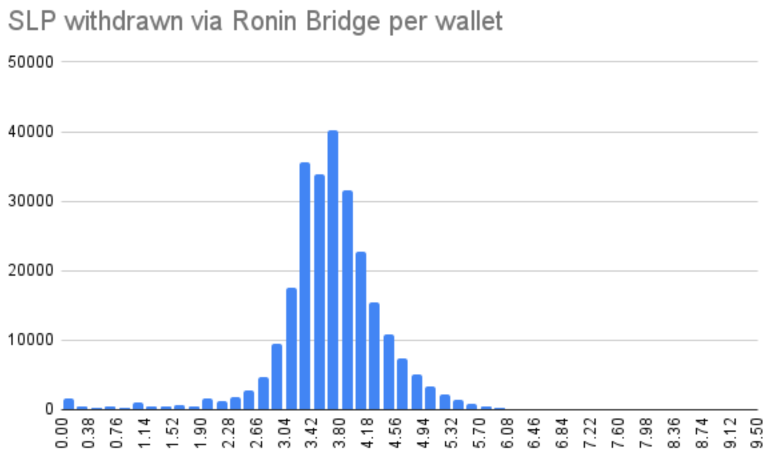

Figure 5.12: A histogram (logarithmic scale) of amounts of SLP withdrawn via the Ronin bridge by wallets. The vertical axis is the amount of SLP (log scale).

source of these incoming trades was Ronin itself, i.e. that these trades owed solely to players cashing out from Axie Infinity. As previously done, we aggregate the trades by date to get a daily volume. Summing across the 6 pairs, we get a total daily volume of SLP traded for another cryptocurrency on Binance. These findings can be seen in figure 5.13.

The findings were unexpected: over the total time period, more than 100 billion SLP had been exchanged for another cryptocurrency on Binance. As the amount of SLP that had been emitted was around 50 billion, we concluded that much of this SLP was not originating from the Ronin network directly. In other words, we deduced that a large portion of this volume was from trades of SLP that had previously come from a third-party (or maybe even Binance itself). This SLP would have already been withdrawn from Ronin (possibly via the bridge), yet it would still be counted in the daily volume. Consider this case: one buys some SLP from Binance for some ETH and then sell it back to Binance when the relative price of SLP goes up. These trades contribute to the trade volume, despite being outside the scope of this project.

As such, there was no purpose for this data for our purposes of studying SLP exiting Ronin.

5.4 Axie prices in the Marketplace

Another potential source of income for Axie Infinity players is by breeding (which costs SLP) Axies and selling them on the marketplace. We began our investigation into this by analyzing the Marketplace contract log data. We initially

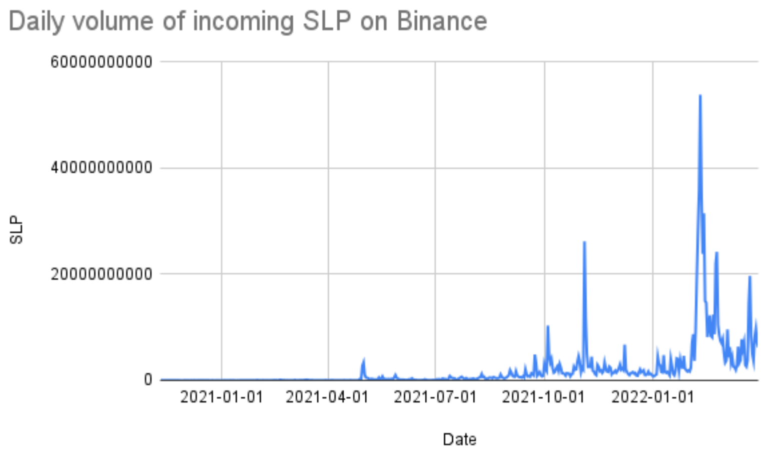

Figure 5.13: A graph of aggregated (across 6 SLP trading pairs) SLP incoming to Binance per day. The vertical and horizontal axes are SLP and date respectively.

looked into the amount of Axies sold per day. This involved aggregating the daily number of transactions in the Marketplace smart contract logs which had the *AuctionSuccessful* succesful tag. The results of this operation can be seen in figure 5.14.

Having calculated the volume of the market in section 5.1.1, we were now able to calculate the daily average price of an Axie sold on the marketplace (see figure 5.15 and 5.16).

Motivated by our findings of the inequality in SLP earnings between players, we wanted to see if there was similar situation in the marketplace. To this end, we aggregated the total earnings on the marketplace by wallet address. Repeating the process from the previous subsection, we made pie charts in figures 5.17 and 5.18 to compare the payoffs for the highest earners to the majority.

Once again, a situation with highly uneven payoffs presents itself. The top 1 percent of players[8] earned more than 60 percent of the total Wrapped Ether exchanged on the marketplace. Furthermore, the top 0.1 percent[9] earned almost a quarter of all WETH from the Marketplace.

[8]The threshold for the top 1 percent is 17.17 ETH, i.e. a wallet would have to receive (at least) that much Ether in the marketplace during the study period to be in the top 1 percent.

[9]The threshold for the top 0.1 percent is 135.74 ETH.

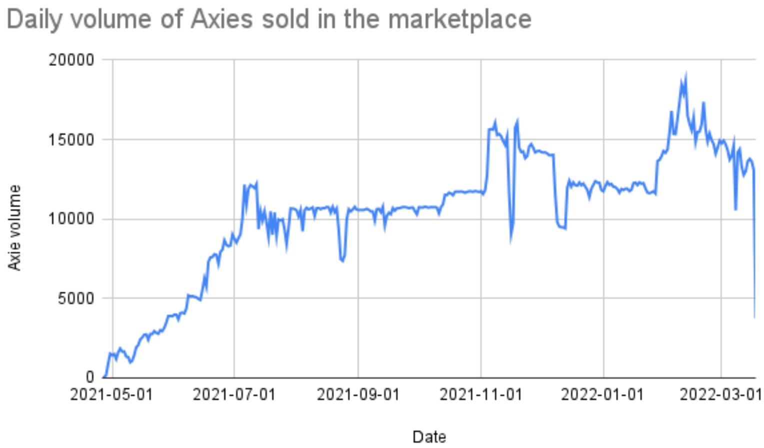

Figure 5.14: A graph of the amount of Axies sold on the marketplace per day. The vertical and horizontal axes are number of Axies sold and date respectively.

Figure 5.15: A graph of the average price in ETH of Axies sold in the marketplace per day. The vertical and horizontal axes are Ethereum and date respectively.

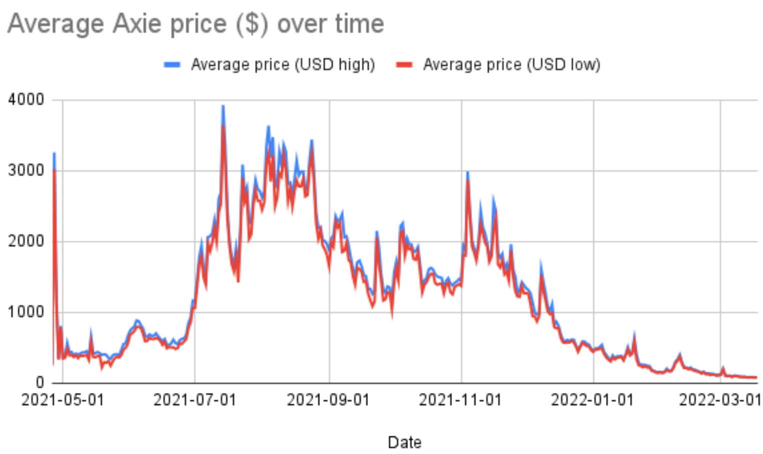

Figure 5.16: A graph of the average price in USD of Axies sold in the marketplace per day. The vertical and horizontal axes are dollars and date respectively.

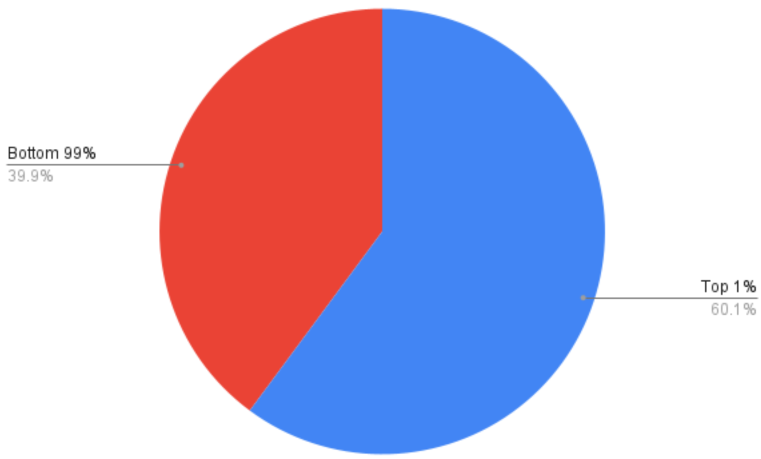

Figure 5.17: A pie chart comparing the amount of ETH earned by the top 1% of wallets (in terms of amount earned) and the remaining 99%.

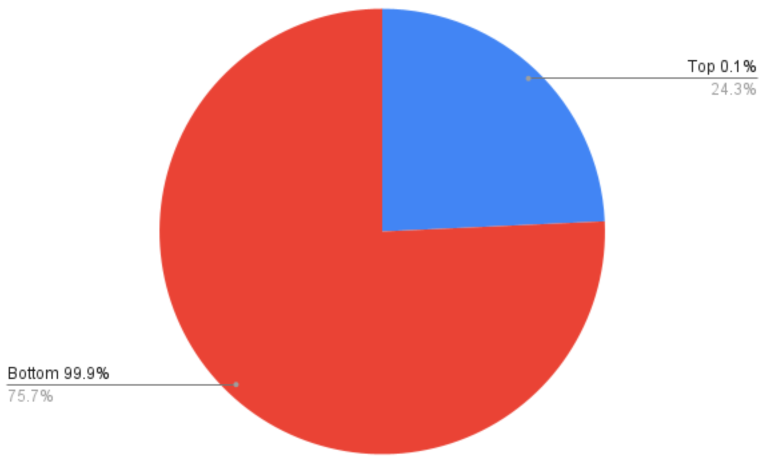

Figure 5.18: A pie chart comparing the amount of ETH earned by the top 0.1% of wallets (in terms of amount earned) and the remaining 99.9%.

5.5 Detection of a possible Ponzi scheme

Motivated by our previous findings, we began to hypothesize that the following pattern could have occurred during the game's lifespan:

- Early players accrue (valuable) Axies in the first months at a relatively cheap price. This could easily be the case as Axie were relatively cheap in the first two months of the game.
- They quickly earn back the money invested on their Axies in SLP. Recalling the previous subsections, the SLP earnings were significantly higher in the first half of the time period we studied. An initial boom and then crash in the USD value of SLP is also responsible for this.
- Having the Axies and the SLP for breeding, the early players are in an advantageous position to breed Axies and sell these on the marketplace to new players.
- New players, especially those who bought Axies at their peak[10], are unable to earn back their initial investment as the value of SLP drops.

This arrangement, whereby the initial investors are paid off by later investors (who are then unable to recuperate their losses), is a Ponzi scheme by definition.

[10] At the peak, a basic Axie (called a "floor" Axie) with low SLP earning potential could cost in excess of $300. This would have involved an initial investment of more than $1000, given that a team of 3 Axies is necessary for playing. Shortly after this peak, the USD value of SLP crashed.

To investigate our hypothesis, we estimate how long it would take to pay off an Axie via SLP earnings for the average player and how this changed over time. In doing so, we incorporate the findings of the inequality between players in terms of SLP earnings. We proceeded as follows:

1. From the data we collected in the previous subsections, calculate the average daily earnings in SLP for players, excluding the top 1 percent of earners.
2. We wrote a script to determine how many days it would take to recuperate an investment on an Axie given SLP earnings.
3. Combining the previous two points, we ran the script using the average daily Axie price and the SLP earnings of the bottom 99 percent. This provides, on a day-to-day basis, the number of days it takes to pay off the average Axie for these players.

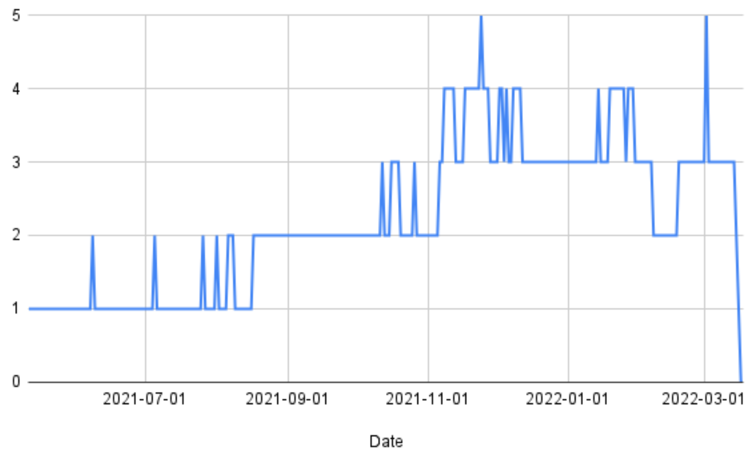

Figure 5.19: Number of days it takes the average SLP earner in the bottom 99% to pay off the average Axie (bought on that date). The vertical and horizontal axes are number of days and date respectively.

As expected, we found a trend of increasing time to payoff the initial Axie investment, which can be seen in figure 5.19. It wasn't as significant as we would have expected (a difference of 4 days at most over the time period we studied). One reason for this could be that the price of Axies tended to decrease in lockstep with the decreasing earnings of SLP. Additionally, we suspected that the average earnings of SLP we were calculating was unrealistically high, despite excluding the top 1 percent of earners.

We then repeated the previous process, this time substituting the average earnings of the bottom 99 percent with the daily median earnings of all players. We conjectured that the median SLP earnings would be more similar to what we had come expect for the earnings of an average player through online research into the game.

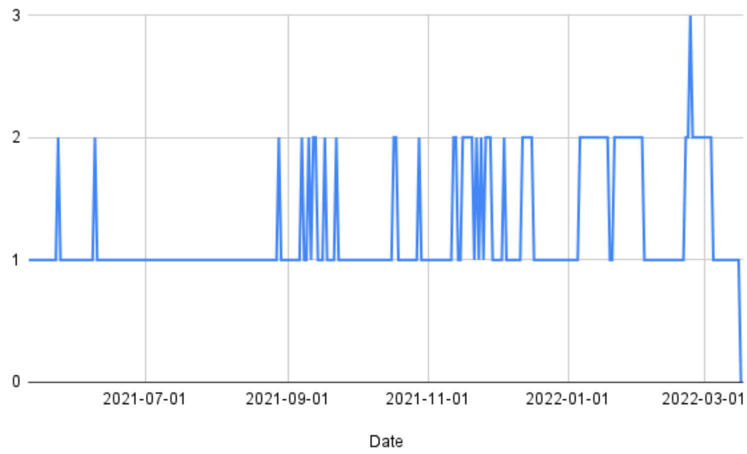

Figure 5.20: Number of days it takes the median SLP earner to pay off the average Axie (bought on that date). The vertical and horizontal axes are number of days and date respectively.

As you can see in the figure 5.20, the outcome did not line up with our expectations. The median daily earnings were in fact higher than the average for the bottom 99%, since it took at most 3 days to pay off an Axie with this approach (versus 5 days when we considered the average of the bottom 99%). Furthermore, there was a only difference of at most 3 days between the longest and shortest time to recuperate the investment on the Axies.

Chapter 6

Conclusions and future work

In our research, we developed a methodology to perform analytical studies of the economy of Axie Infinity, which is the most popular "play-to-earn" (P2E) game based on the blockchain. It is classified as GameFi — a category of games built on decentralized systems offering real world financial incentives to players. This work has been motivated by concerns related to the P2E economical model's viability and vulnerabilities of the underlying, decentralized, blockchain technology. During our work, we applied data mining and analysis techniques to the study of a Axie Infinity's blockchain. We developed a solution for collecting the game's smart contract logs and a processing pipeline to refine the logs. We demonstrated how metrics are applied to this data to gather insights into the game's economy. Along the way, we explored and analyzed the data to find patterns that could indicate the presence of imbalances and anomalies, and other interesting properties of the game's economy.

6.1 Discussion

We have successfully demonstrated an approach to collecting and analysing data from the blockchain game Axie Infinity. Key contributions are highlighted as follows:

- In section 4.1, we show how to utilise the Covalent API and Binance trade history to collect game data, and how issues relating to the large size of the data were resolved.
- In section 4.2, we described the format of a smart contract log, which proves useful in the refinement of the data. We then go on to introduce a pipeline to processes the data. We subsequently provided solutions for problems caused by the amount of data involved in our studies.
- In chapter 5, we present the metrics that were developed and the results that they provided. This involved introducing an iterative process, which entailed developing and applying the metrics, observing the findings and

reflecting on the insights that we have gathered in the process. The 5 subsections of this chapter represent 5 instantiations of the this process, each one motivated by the preceding one.

6.2 Future work

GameFi and blockchain technology in general is rather a recent phenomenon. Therefore, our research methodology can be extended in a variety of ways. An obvious extension would be applying this approach to other blockchain games or decentralised applications. A comparison with our study and the findings of this thesis can be then used to determine whether large inequalities between users is commonplace in this category.

Additionally, one could survey previous and current players of Axie Infinity to learn about their firsthand experiences, their actual earnings from the game and how Axie Infinity has altered their view of blockchain gaming and technology in general. This empirical approach could be supplemented by calculating, for every wallet address, the incoming and outgoing tokens from an Axie Infinity wallet and determining whether the average Axie player has obtained a reasonable payoff (or has incurred losses).

Finally, one could widen the scope of study to "play-to-earn" blockchain games as a whole, investigating how this emergent category has changed over time, especially considering the recent crash in cryptocurrency prices. We see evidence of adaptation from Sky Mavis themselves (the developers of Axie Infinity), who, after a significant drop in daily active players and the earnings these players can expect, released a new version of their existing game, namely Axie Infinity: Origin [2, 20]. This game, which promises to enable new users to "fall in love with the universe before needing to touch crypto and NFTs!", allows players to begin playing the game without an initial investment for Axies. Furthermore, the "play-to-earn" aspect of the game is strongly diminished, as player-versus-environment battles no longer reward Smooth Love Potion. Has Sky Mavis positioned itself to move towards a traditional gaming model, as it doubts the viability of the "play-to-earn" model? This scenario can be evaluated by extending the methodology we developed in our research.

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