Gamification Based Blockchain Tournaments Between Miners

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Kenta, H., Shino, Y. ., Immaniar, D. ., Harahap, E. P. ., & Ahmad, A. D. A. R. (2021). Gamification Based Blockchain Tournaments Between Miners. *Aptisi Transactions on Technopreneurship (ATT)*, 3(1), 91–114.
DOI: <https://doi.org/10.34306/att.v3i1.144>

Author Notification
20 January 2021
Final Revised
11 February 2021
Published
31 March 2021

Abstract

We have modelled mining resource and cryptocurrency-related relationships into a non-cooperative game. Then we took advantage of the traffic congestion results, set a native convention for the Nash equilibria, and created a short algorithm to find the equilibria. Next, we will make calculations for several system models whose variations follow the existing mining resources and have appropriately allocated according to the details of the mining complexity level that has defeated. In the included resources, the game's result is the allocation of resources as a feature of a normalized Nash equilibrium. In the model that has proposed, we provide a property structure of the type of equilibrium that exists, such as a condition where there are two or more mining infrastructures that will be active and another state that explains that no Miners get results in wanting a specific cryptocurrency, like bitcoin.

Keywords: Competition, Mining, Bitcoin, Blockchain, Game Theory

1. Introduction

The blockchain is a distributed database that contains validated block transactions [1]. The block will be validated with a unique node, and these particular nodes are called miners, the validation of each block done with such a complex computation that it is called a proof-of-work puzzle [2]. Miners compete with others to solve a computation that is so complex and to be the first to solve the problem, the block that has solved will be verified by other miners on the same network when the block is spread and reaches a consensus [3].

The block will enter the database, and Miners who solve a complicated computational will get a cryptocurrency for the compensation to solve the complicated computational. Solving such a complex problem requires enormous resources and is usually done with special hardware [4]. An ESP or edge computing service introduced to support proof-of-work using edge computing nodes [5]. A game formulated among miners by presenting a single ESP and a game called the Stackelberg game to calculate prices that maximize ESP revenue. in this research, we ask two questions:

1. First, with a single blockchain, how do users directly contribute to the mining process, and make it possible to calculate costs and lower infrastructure costs?
2. Second, given a multiply-blockchain, as in a multi-cryptocurrency ecosystem, how can active users distribute their monetary and/or computing budgets in blockchain miners.

In this research, our focus is on competition between miners which refers to the two questions above [6]. We will give an example of competition among miners, then choose ESP, and Blockchain which will be used as a non-cooperative game [7]. Each ESP associated with the miners' infrastructure will be separate, and each blockchain that is compatible with the cryptocurrency will be different. We will then filter the results on two examples of games in general, namely the Nash equilibrium Properties [8].

There is a single blockchain (example: Cryptocurrency) and one of the M ESPs (or mining pools) that miners can use to solve a computational problem that is so complex [9]. In the second game, we used K odds, each of which is related to one another. In each slot with a T duration (the time that corresponds to the problem solving), [10] the miners decide which K puzzle to solve. We have formulated both games and have set a Nash equilibrium to solve the problem between the miners and the ESP and provide a simple algorithm for solving it [11]. Moreover, we have summarized it as follows:

Congestion Games for mining competition: we have made an example based on users looking for solutions to problems (Section 3). As the number of miners increases [12], the chances of competing for solving puzzles and being rewarded for achievements decrease. We assume that users can rely on roughly indistinguishable third parties [13], further proof that when there is a cryptocurrency of interest, Congestion Games with simple equilibrium calculations for users should not join any system (Section 4).

Analysis of multi-cryptocurrency ecosystem: We analyze the Congestion Game, which has involved many cryptocurrencies. Miners compete to mining the same cryptocurrency (Section5), and we have seen that the game has potential [14].

Continuous actions and physical bounds on resources: We have considered a lot of the two things that we propose for further action. First, miners can split their budget across multiple ESPs and Cryptocurrencies (section 7.1) [15]. Second, we limit the resources that can be used by all parts of the system (section 7.2) [16]. This paper is structured as follows: Section 2,3 presents competition mining background and an overview of the game framework to characterize that competition. Part 4 is devoted to setting where there is only one cryptocurrency, [17] lastly in section 5 accounts for multiple cryptocurrencies. General calculations for Multiple ESPs and Multiple Cryptocurrencies will discuss in section 6. Extensions to account for future actions and limits on resources discuss in section 7. Discussion on related work is in section 8.9, and in section 10 is conclusions [18]. Then the appendix contains additional material including a discussion of positive, [19] and hostile miners externalities (appendix A) proof techniques (Appendix B) and an analysis of the settings in which ESPs continue to use resources at maximum capacity (Appendix C).

2. Research Method

2.1 Literature Review

There are lots of literature reviews that discuss blockchain game theory [20] [21] [22] [23] [24] [25] [26] the literature on congestion games that have been applied to the system is still very difficult to find. There is no previous research that discusses competition miners on blockchain networks, and their relationship to multicryptocurrencies. Congestion games have been widely applied in the aspect of security [27] the price of an infrastructure [28] [29] [30]. The author studies bitcoin as one of the congestion games. where game congestion occurs due to an increase in the number of users and transactions. we separate from some aspects of

competition among miners. we focus on the competition between miners [31]. implement a framework of congestion games to provide an example of competition between miners who try to maximize utility by choosing the cryptocurrency to be mined. We proved that there is no standard potential function for the proposed game. jami refers to readers of [32] and [33] for additional references on the multi-cryptocurrency ecosystem [34]. started a study that discussed the introduction of crypto-anarchy based on an introduced model [36]. In this case, and we focus on the competition between miners. We envision a more in-depth study of the loss of efficiency due to a lack of controllers and a study of authority's role in regulating the crypto market. And that is an important thing, and that topic can be the subject of future research.

2.2 Mining Competition

In this section, we will discuss two related aspects [35]. First, we will show how a granularity adjusts the miners' difficulty level, and it impacts the nature of the competition (section 2.1). Next, we link the details on adjusting mining difficulty (section 2.2). We have shown extensively how competition and cooperation occur, and they all play an essential role in the blockchain system.

2.3 Granularity of Adjustment of Mining Complexity

The purpose of adjusting the mining complexity is to find the most challenging point in the block network, which contains lots of new blocks every second. in bitcoin, we have $x = 10$ minutes. By reducing the difficulty level, the Bitcoin protocol can also reduce the amount of time it takes to process resources, and electricity required to complete a block.

Next, we will discuss an implication of granularity where a mining complexity level can be adjusted. Such as adjusting the difficulty level of the algorithm from bitcoin, naturally, it can be adjusted by the system every 2016 new blocks appear. These adjustments occurred on average at two-week intervals [36]. In the present study, we considered two cases associated with granularity.

2.4 Fine grained adjustment of mining complexity

When fine-tuning the complexity level, the miners enter and leave the network every time the complexity level is automatically adjusted. In this case, the time the miners complete is independent of quantity. In the viewpoint of the miners the time that a puzzle completes increases as the number of miners increases.

2.5 Coarse grained adjustment of mining complexity

In a rough solution of complexity, the number of miners varies, now the time spent decreases as the number of miners increases. In the third part, we will explain the general game, then consider the two scenarios described above and give specific results for the two examples above [37].

2.6 Horizon of Competition

The horizon of competition that occurs among miners depends on the granularity in which adjustments can occur. When the adjustment occurs, competition occurs both in a short and extended time. This happens because the number of miners continues to grow. Furthermore, the competition between miners becomes more aggressive; on the other hand, under the rough adjustment of the mine's complexity and occurs quickly. The point is that miners continue to compete in deciding who will mine in the next block (see Figure 1).

Figure 1. Horizon of Competition

3.BLOCKCHAIN COMPETITION GAME

3.1 Basic Concepts

Miners, Mining Servers, and Puzzles. we have decided considering the population of M ESP, and a set of cryptocurrencies, where cryptocurrencies will be linked to other blockchains. We have given the value $N = \{1, 2, \dots, N\}$ a set of miners, also known as users. The population of value miners is minimal. Furthermore, if you change the strategy, then this will change the utility of the miners. Suppose $K = \{1, 2, \dots, K\}$ and it shows a set of Puzzles and related to another, and that is different from the cryptocurrency that continues to be solved, we assure you that every puzzle will be the same as cryptocurrency. after this $M = \{1, 2, \dots, M\}$ M is mentioned as a set of ESPs or also known as server miners, virtual ESPs specifically for indet value 0. Miners enter with ESP 0 when they decide not to join the competition game. summarized in table 1.

Strategies. Given a set of $SI \subset K \times M$ sets and it shows sequentially (puzzle, ESP), the ESP that miners can rely on to solve a particular puzzle. A set of SI sets differs between miners due to limitations. An alternative to it all is a set of ESPs available for two different miners, and unlikely to be the same. The miners' strategy of I will be denoted by $si \in Si$, and it corresponds to the puzzle the miners want to solve. The strategy $si = (k, m)$ is following I which uses the ESP m infrastructure in mining, the Strategy Vector $s = (si) \mid I \in N$ will produce a load vector $I = (lk, m) \mid k, m$, where lk, m denotes the number of miners and use ESP for mining.

Mining complexity. We have shown that uk, m, I have the service level of the ESM m that miners I have been asked to solve in the k puzzle. We give the $\mu_{k,m,i} > 0$ when $m \neq 0$, and $\mu_{k,0,i} = 0$, for $k = 1, \dots, K$ and $i = 1, \dots, N$. For convenience, the service rate is measured:

- in the calculated hash, when taking into account the very detailed adjustments of the complex miners, where the number of completed puzzles is assigned and assigned
- in the finished puzzle with rough solutions simplifies notation 1. And let nk be a load of miners in all ESPs and passed to k

TABLE 1 | Table of notation.

Variable	Description
K	Number of blockchains (cryptocurrencies)
M	Number of edge service providers (ESPs)
N	Number of miners (willing to mine using ESPs)

$U_{k,m}(\ell)$	Utility of user mining blockchain k at ESP m
$\gamma_{k,m}$	Mining cost associated to blockchain k at ESP m
$\mu_{k,m}$	Service rate from ESP m requested by each miner to solve puzzle k
$S_i \subset K \times M$	Action space and corresponding variables
S_i	Set of ordered pairs (puzzle, ESP), Corresponding to ESPs that miner i Can use to mine k
$\ell_{k,m}$	Number of users mining blockchain k at ESP m
ℓ	Strategy profile, $\ell = (\ell_{1,1}, \ell_{1,2}, \dots, \ell_{k,m}, \dots, \ell_{K,M})$ (discrete action space, all sections exception section 7)
Control Variable	
s_i	$s_i = (k, m)$ if user i mines blockchain k at ESP m (discrete action space, all sections except section 7)
x_m	Amount bid by ESP m , proportional to the load invested by ESP m for mining (continuous action space, section 7)
Metrics	
$\rho_{k,m}(\ell)$	Probability that user is first to mine a block

$$\eta_k = \sum_{m' \in \mathcal{M}} \sum_{i' \in \mathcal{N}} \mu_{k,m',i'}.$$

TABLE 2 | Granularity of difficulty adjustment.

	Average time between two blocks mined, for whole population	Average time between two blocks mined, per miner	Probability of success by time T	Time horizon to grant rewards to given player
	(T_k)		(q_k)	(T)
Fine grained		Variable, depends		Large, compared
adjustment of mining complexity	Fixed and given	on η_k , for fixed $\mu_{k,m}$	≈ 1	against puzzle complexity adjustment
Coarse grained	Variable, depends			Small, compared
adjustment of mining complexity	on η_k , for fixed $\mu_{k,m}$	Fixed and given, for fixed $\mu_{k,m}$	$1 - \exp(-T\eta_k)$	against puzzle complexity adjustment

On the other hand, except as stated, we assume that the selected user we provide are then allocated with the hash provided by ESP2. Figure 2 illustrates the settings under consideration then simplified into note that (2) is obtained from (1) by combining space: for symmetrical use, it is sufficient to keep track of the number of users who have made their choice (ESP, and Cryptocurrency) available. Then T_k becomes the time required for the first mining of all ESPs. To solve the problem of k , suppose q_k is a probability of the puzzle k being completed over time T . Note that such a complex adjustment in mining T_k and Q_k is functionally not significantly depends on n_k as far as the number of mining k that exist.

We assume that the desired time horizon, T is set to such an enormous value, independent of n_k so that $q_k \approx 1$. Under the rough adjustment of mining complexity, t_k and q_k depend on NK as the time taken in a block of cryptocurrency k to succeed. in mining and can be continued to k . **(table 2).**

In solving complex complexities for miners T_k depends on the number of miners. In this case, we are telling that with $R_{k,m,i}$ the amount of time it takes i to solve the puzzle k . since our assumption is symmetrical use, the random variables $R_{k,m,i}$ do not depend on a particular distribution identically, for $i = 1, \dots, N$, with each $R_{k,m,i}$ distributed exponentially with the rate $\mu_{k,m}$. so if l_k miners are dealing with ESP m with currency k , it will take speedy time for them to finish it. for currency k , which is distributed exponentially with the exchange rate $\eta_k = m \mu_{k,m} l_{k,m}$.

$$T_k \sim \text{Exp}\left(\sum_m \mu_{k,m} \ell_{k,m}\right)$$

$$q_k = 1 - \exp(-T\eta_k).$$

Note that in this case, if T is adjusted to a large enough value, also depending on η_k , we also have $q_k \approx 1$ as above. **Rewards and costs.** Let $p_{k,m}$ tell us that the probability that the miners using esp is the first to solve the puzzle of k in state l .

$$\tilde{p}_{k,m}(\ell) = q_k \frac{\ell_{k,m} \mu_{k,m}}{\eta_k}.$$

Throughout this paper, $0/0 = 0$. In the expression of $\tilde{p}_{k,m}$, for instance, if $\eta_k = 0$ and $\ell_{k,m} = 0$, then $\tilde{p}_{k,m} = 0/0 = 0$. Under strategy profile ℓ , the probability that a given miner using ESP m is the first to solve puzzle k is:

$$p_{k,m}(\ell) = 1_{\ell_{k,m} > 0} \frac{q_k \mu_{k,m}}{\eta_k},$$

where 1_c equals 1 if condition c holds and 0 otherwise. We tell you that with $y_{k,m}$ as the cost of mining blockchain k in ESMP, under such complex complexity adjustments, $y_{k,m}$ is measured in time. The complexity of the puzzle $y_{k,m}$ is the user's cost during the use of resources for a particular time. Utilities. Let $U_{k,m}(\ell)$ denote the utility to a miner who tries to find the answer of puzzles associated to cryptocurrency k , using ESP m . The utility is given through rewards minus costs.

$$U_{k,m}(\ell) = \begin{cases} p_{k,m} \rho - \gamma_{k,m} & \text{if } m > 0, \\ 0 & \text{otherwise.} \end{cases}$$

Under the fine grained adjustment of puzzle quality, ρ is that the rate reward granted to winning miners, that is fastened and given. Therefore, to alter presentation we tend to let $\rho = 1$, and $\gamma_{k,m}$ is adjusted consequently. beneath the coarse grained adjustment of puzzle quality, in distinction, if users are still inquisitive about the long run rewards they have to account for a rate reward that's a perform of the users actions. this is often as a result of beneath the coarse grained adjustment of puzzle quality, the larger the quantity of users mining a given cryptocurrency, the larger the speed at that blocks are deep-mined. or else, driven by Bissias et al. (2019) we tend to assume that users beneath the coarse grained adjustment of puzzle quality are greedy and myopic, as elaborated next [38]. Whereas beneath the fine grained adjustment of puzzle quality users have an interest in maximising an extended term average rate reward, beneath the coarse grained adjustment they're inquisitive about maximising the reward collected by time T , assumptive that in that point horizon the possibilities that quite one user collects rewards are negligible. in this case, users are granted a present if and providing they're the primary to with success mine by the time horizon of interest, T . we tend to let $\rho = 1$ and $\gamma_{k,m}$ characterizes the price of reserving mining resources to mine throughout slot T .

Note that beneath the fine grained adjustment of puzzle quality, a replacement mining interval starts right away when a winning mining event happens. beneath the coarse grained adjustment of puzzle quality, in distinction, we tend to assume that mining resources are reserved for a mining interval T , and even if successful happens before T miners buy resources allotted up till T . In each cases, the utility reduces to:

$$U_{k,m}(\ell) = \begin{cases} p_{k,m} - \gamma_{k,m} & \text{if } m > 0, \\ 0 & \text{otherwise.} \end{cases} \quad (8)$$

User i utility is $\tilde{U}_i(s_i, s_{-i}) = \sum_{(k,m) \in S_i} 1_{s_i = (k,m)} U_{k,m}(\ell)$, where $s_{-i} = (s_1, s_2, \dots, s_{i-1}, s_{i+1}, \dots, s_N)$ is the vector of strategies of all miners except miner i . Given the

ingredients above, the blockchain competition game is characterized by $C = \langle N, K \times M, (S_i)_{i \in N} (U_{k,m})(k,m) \in K \times M \rangle$. In sections 4 and 5 we analyze two special instances of this game.

3.2 Summary of Terminology

We summarize the fundamental language used throughout this paper.

- **Edge Service suppliers (ESPs)** endlessly attempt to solve blockchain puzzles by allocating hash power for that purpose.
- **Hash power** dedicated to a given blockchain by a given ESP is that the variety of hashes computed per unit of time by that ESP to solve puzzles from the corresponding blockchain.
- **Service rate** dedicated to a given blockchain by a given ESP equals the corresponding hash power. below the coarse-grained adjustment of puzzle quality, it is a lot of convenient to live the service rate in a variety of in puzzles resolved per unit of time, noting that during this case, the amount of in puzzles resolved per unit of time equals the hash power times a constant increasing issue smaller than one.
- **Miners** pay to ESPs to resolve blockchain puzzles.
- **Active miners** participate within the mining game by paying a strictly positive quantity to ESPs to resolve blockchain puzzles.
- **Inactive miners** decide not to be part of the mining game actively. They receive no rewards and incur zero prices.
- **Rewards** square measure granted to miners once the contracted ESP solves the corresponding puzzle.
- **Costs** square measure incurred by miners to contract ESPs.
- **Revenue** corresponds to rewards minus prices incurred by every laborer.
- **Congestion Games and Potentials** Next, we have a tendency to, in brief, introduce some basic background on congestion games, state of affairs games, and potentials. Congestion games were introduced by Monderer and Shapley (1996) and are similar to routing over a whimsical graph, once all routed objects have an equivalent size and are nonsplittable. The value of victimization a footing is that the same for all players. Situation games planned by [39] congestion games with additional restricted topology (parallel links), however, additional general prices (user dependent).

In our setup, the routed object is that the mining power. The network incorporates a bipartite topology, wherever one facet consists of mining users (end users), and also the alternative facet consists of ESPs that mine consistent with mining users' requests. A virtual ESP corresponds to the choice of not mining. incurred by a user WHO decides to mine through a given ESP is that the cost of a footing between the user and also the ESP.

A congestion game without players' own gain features is guaranteed to admit a standard potential and pure balance. A game that does not allow a standard potential can still allow an ordinal potential. A game with an ordinal potential can have any finished subset of actions at the disposal of a player, always admitting a pure balance [40]. Proves the existence of a pure Nash balance taking into account user-dependent costs in crowd games. In this paper, we focus on user-dependent policy packages.

4. ESP CONNECTION GAME

In this section, we introduce the ESP connection game and examine some of its equilibrium properties. We consider the particular instance in which we have only one cryptocurrency, which we denounce.

Coarse Grained Adjustment of Mining Difficulty, in this section, we consider adjusting the mining complexity level, where there is a single cryptocurrency. First, we will consider the easiest setting with everything symmetrical. (section 4.1.1). Then we give leeway from our assumptions and show where the mapping between the ESP Connection games and the potential that exists, then give an estimate of the extent to which the assumption can still be easier (section 4.1.2)

To Mine or Not to Mine? A Simple Congestion Game Accounting for Symmetric ESPs in this section, we aim to illustrate the relationship between the game under consideration and the congestion game. For that, we have assumed Symmetric ESPs i.e., μ^* , $m = \mu^*$ and γ^* , $m = \gamma^*$ for m . although very simple, and it can serve to analyze which can be considered in this paper. In the next section, we will simplify these assumptions. Let I will be the number of miners that decide to use the ESP

$$\ell_{\star} = \sum_{m=1}^M \sum_{i \in \mathcal{N}} 1_{s_i^* = (\star, m)}.$$

then $N - I_{\star}$ is said to be the number of users who have decided not to mine. if all μ^* , m are the same, then μ^*

Equation (6) reduces to:

$$p_{\star}(\ell_{\star}) = 1_{\ell_{\star} > 0} \frac{1 - \exp(-T\mu_{\star}\ell_{\star})}{\ell_{\star}}, \quad (10)$$

$$\operatorname{argmax}_{\ell_{\star}} \sum_{l=1}^{\ell_{\star}} (p_{\star}(l) - \gamma_{\star}) \quad (11)$$

$$\text{subject to: } \ell_{\star} \leq N, \quad \ell_{\star} \geq 0, \quad (12)$$

$\ell_{\star}$ is the solution of (11) - (14) the number of users who have decided to mine. equation (11) is the potential of each player, the optimization problem (11) - (14) is the same as the bin problem.

PROOF: a meaning of congestion game in Rosenthal's (1973) [41] sense, and it has potential. In this game, the player can decide whether to use ESP or not. All connections to M ESP can be easily combined into a single route that represents each miner's choice. Furthermore, the option to unlink represents a second route (see Figure 3).

THEOREY 2 (player strategy). If the receiver is on the user l , in this game sense, may not be willing to recognize the potential of each of them but still recognize Pure Nash equilibria.

Proof: This is the crowding following the results from Milchtaich.

4.1 Existence of Equilibrium Under General Conditions

Our next goal is to illustrate the results of equilibria. We, therefore, generalize the conditions in the previous section that allows for some non-symmetric ESP and show how being considered a game is still related to game congestion.

THEOREM 3 (existence). If $\gamma_{\star, m} = \gamma_{\star, m'}$ for all m' and m , $\mu_{\star, m} \neq \mu_{\star, m'}$ for all m and m' such that $m \neq m'$, and $S_i = S_j$ then:

1. a pure Nash equilibrium exists
2. miners will only rely on ESP m^* , with $m^* = \max\{m : \mu_{\star, m} \geq \mu_{\star, m'} \forall m'\}$ and
3. the Nash equilibrium is given by the solution of the following optimization problem,

$$\operatorname{argmax}_{\ell_{\star, m^*}} \sum_{l=1}^{\ell_{\star, m^*}} (p_{\star, m^*}(l) - \gamma) \quad (13)$$

$$\text{subject to: } \ell_{\star, m^*} \leq N, \quad \ell_{\star, m^*} \geq 0. \quad (14)$$

PROOF : let $\ell_{\star, m}$ be number of users, except one, mining the cryptocurrency using ESP m . $\ell_{\star, m}$ needs not to be at Nash Equilibrium. The player that did not take his decision is facing the following optimization problem:

$$\max \left\{ \max_m \left\{ \frac{\mu_{\star, m}(1 - \exp(-T(\mu_{\star, m} + \sum_{m'} \ell'_{\star, m'} \mu_{\star, m'})))}{\mu_{\star, m} + \sum_{m'} \ell'_{\star, m'} \mu_{\star, m'}} \right\}, \gamma \right\}. \quad (15)$$

Let us define the function f such that:

$$f(x) = \frac{x(1 - \exp(-T(x + \sum_{m'} \ell'_{\star, m'} \mu_{\star, m'})))}{x + \sum_{m'} \ell'_{\star, m'} \mu_{\star, m'}}. \quad (16)$$

$f(x)$ is strictly increasing for $x > 0$. Therefore, for all $\ell'_{\star, m'}$:

$$\begin{aligned} \max_x f(x) &= f(\mu_{\star, m^*}) \\ &= \frac{\mu_{\star, m^*}(1 - \exp(-T(\mu_{\star, m^*} + \sum_{m'} \ell'_{\star, m'} \mu_{\star, m'})))}{\mu_{\star, m^*} + \sum_{m'} \ell'_{\star, m'} \mu_{\star, m'}}, \end{aligned} \quad (17)$$

with $m^* = \max\{m : \mu_{*,m} \geq \mu_{*,m'} \forall m'\}$. It follows that the utility of a player at equilibrium will be:

$$\max \left\{ \frac{\mu_{*,m^*}(1 - \exp(-T(\mu_{*,m^*} + l'_{*,m^*}\mu_{*,m^*})))}{\mu_{*,m^*} + l'_{*,m^*}\mu_{*,m^*}} - \gamma, 0 \right\}. \quad (18)$$

The result of that is the best response from each user for every l^* , m is the miners who rely on ESP m^* , with $m^* = \max\{m : \mu_{*,m} \geq \mu_{*,m'} \forall m'\}$. Furthermore, we will gather each user and focus on ESPm. It is in Rosenthal's (1973) sense that the remainder is associated as a special case of Theorem 1. in congestion game networks. The time it takes for it (the number of attempts that have taken place to become miners) wherever it is increasing. the function of the number of miners who select ESP. and according to theorem 1, there is a Nash equilibrium

4.2 Illustrative examples

Consider 4 miners and 3 ESPs, $N = 4$ and $M = 3$. Let $\mu_{*,m}$ equal 0, 0.2, 0.4 and 0.6 for $m = 0, 1, 2, 3$, severally. Let $T = 1$ and $\gamma = 0.3$. Then, the sport admits vi pure equilibria, wherever $vi = 42$. In every equilibrium, 2 of the players adopts strategy zero and also the different 2 players adopt strategy three. The players adopting methods three and zero have corresponding utilities of zero.049 and 0, severally, wherever $vi = 3$. additionally, $p_{*,m}(l) - \gamma$ equals zero.15, 0.049, -0.02, and -0.09 for $l = 0, 1, 2, 3$, indicating that l^*, m^* ($p_{*,m}(l) - \gamma$) is maximized for $l^*, m^* = 2$ that is in $m=1$ agreement with the very fact that two users area unit active in equilibrium. Consider currently the subsequent extra example, that is out of the scope of Theorem three, whereby four miners vie over three ESPs, $N = 4$ and $M = 3$. Let $\mu_{*,m}$ equal 0, 0.24, 0.45, and 0.6 for $m = 0, 1, 2, 3$, severally. Let $\gamma_{*,m}$ equal 0, 0.147, 0.26, and 0.46 for $m = 0, 1, 2, 3$, severally. Note that Theorem three assumes $\gamma_{*,m}$ to be a similar across all ESPs, that isn't the case within the current setup. This game admits nineteen pure author equilibria: twelve equilibria correspond to permutations of the strategy profile (0,1,1,2), vi equilibria correspond to permutations of the strategy profile (0,0,2,2) and also the last equilibrium equals (1,1,1,1). Note that strategy three, that corresponds to the very best rate, doesn't seem in any of the equilibrium profiles. this can be in stark distinction with the previous setup, wherever in the strategy with highest rate was the sole candidate to be a part within the equilibrium. additionally, note that users adopting totally different strictly positive rates might along comprise the equilibrium. This motivates the subsequent conjecture.

' CONJECTURE four. If (i) $\mu_{*,m} \neq \mu_{*,m'}$ whenever $m \neq m'$, (ii) $\gamma_{*,m} \geq \gamma_{*,m'}$ implies that $\mu_{*,m} \geq \mu_{*,m'}$, and (iii) $S_i = S_j$ then:

TABLE 3 | Assumptions throughout sections.

Section	ESPs	Symme- tric ESPs	Users can decide not to mine	Puzzle complexity adjustment	Multiple ESPs	Multiple crypto	Atomic miners	Conti- nuous actions
4.1.1	One or more	Yes	Yes	Coarse	Yes	No	Yes	No
4.1.2	One or more	No	Yes	Coarse	Yes	No	Yes	No
4.2	One or more	No	Yes	Fine	Yes	No	Yes	No
5	One	No	Yes	Coarse	No	Yes	Yes	No

6	One or more	No	Yes	Fine	Yes	Yes	No	No
				or coarse				
7	One or more	No	Yes	Fine	Yes	No	Yes	Yes

1. a pure Nash equilibrium exists
2. at equilibrium, across the set of active miners there will be connections to at most two ESPs, denoted by m' and m'' and
3. when $m' \neq m''$, the Nash equilibrium is given by the solution to the following optimization problem,

$$\operatorname{argmax}_{(\ell_{*,m'}, \ell_{*,m''})} \sum_{l'=1}^{\ell_{*,m'}} \sum_{l''=1}^{\ell_{*,m''}} p_{*,m'}(\ell) - \gamma_{*,m'} + p_{*,m''}(\ell) - \gamma_{*,m''} \quad (19)$$

$$\text{subject to: } \ell_{*,m'} + \ell_{*,m''} \leq N, \quad \ell_{*,m'} \geq 1, \quad \ell_{*,m''} \geq 1, \quad (20)$$

where $l = (N - l' - l'', l', l'')$ denotes a strategy profile wherein $N - l' - l''$ miners are inactive, l' miners adopt ESP m' and l'' miners adopt ESP m'' . to describe the last part. pay attention to the results of the previous one. Suppose $m' = 1$ and $m'' = 2$, then let the profile that is combined with the vector be (n_0, n_1, n_2, n_3) , [41] which is appropriate where users use ESP i . then the combination of $(2,1,1,0)$, $(1,1,2,0)$, $(0,1,3,0)$, $(1,2,1,0)$, $(0,2,2,0)$, and $(0,3,1,0)$ and the evaluation of the objective function (19) becomes 0.0914, 0.0961, 0.0345, 0.1336, 0.1055 and 0.1333. it shows that the profile balance is $(0, 1, 1, 2)$ and found in the previous paragraph, which corresponds to the profile that has been put together $(1, 2, 1, 0)$.

4.3 Fine Grained Adjustment of Mining Difficulty

Next, we tend to contemplate the fine-grained adjustment of the mining problem. Thereto aim, we tend to assume $q_k = \text{one}$, i.e., we tend to don't embrace the exponential term within the definition of q_k (Equation 4). Recall that the exponential term captures the chance that the puzzle isn't resolved by time T , which we tend to assume to be negligible (i.e., abundant smaller than 1), for big enough T (see Table 3).

4.4 Best Response Dynamics and Convergence Under M -concave Potential

Consider any higher response learning theme. Specifically, the most effective response learning theme is one in every of such schemes. Note that for a player to update its response, it solely has to have access to the entire load across all ESPs. Note conjointly that for a player to compute its response, while not previous data of historical responses, it has to understand the general load generated by all the miners over every esp.

Since the utility is cup-shaped, we tend to might expect the potential to converge to a world optimum in finite time beneath any normal best response strategy or higher response policy. However, the cup-shaped operation is outlined solely on integers, which isn't an umbellate compact set. During this case, some modifications of the definition of concavity and umbellate sets area unit are required so as to ensure that any native extremal purpose of the operation may be a world extremal purpose. These modifications area unit referred to as M -concavity and M -convex set, severally (see Lebeau et al., 2019 and references therein). Then, the key results of this section follow.

THEOREM 5. *The ESP competition game under fine grained adjustment of mining difficulty admits a potential.* PROOF: it's shown in Lebeau et al. (2019) that the social medium choice game could be a congestion game. We've got already shown that the psychic phenomenon choice game could be a congestion game, which there exists possible. The potential operate for the social medium choice game is additionally a possible operate for the psychic phenomenon choice game. Moreover, Theorem two from Lebeau et al. (2019) shows that the potentials area unit M-concave functions are outlined over AN M-convex set [9].

4.5 Cryptocurrency Association Game

In this section, we tend to introduce the multiple cryptocurrencies game and derive structural properties of the associated set of equilibria. As in section four.1, we tend to assume a rough grained adjustment of problem level. additionally, we tend to assume that there area unit K cryptocurrencies. we tend to think about one psychic phenomenon, and drop subscript m from all variables.

For a given load vector l , the time it takes until the quickest puzzle to be resolved is exponentially distributed with expectation $1/(\mu_k l_k)$. Thus, the likelihood that a mineworker is that the initial to unravel the puzzle is:

$$p_k(l_k) = \frac{1 - \exp(-T\mu_k l_k)}{l_k}. \quad (21)$$

Note that $p_k = 0$ if $l_k = 0$ (recall that we assume $0/0 = 0$ throughout this paper). The utility of a tagged miner to mine a cryptocurrency k when there are l_k miners associated with the same cryptocurrency (including the tagged miner) is given by (8), where:

$$U_k(l_k) = p_k - \gamma_k. \quad (22)$$

We raise it the constraint that a laborer doesn't participate in resolution the puzzle if its utility is negative. in this case the equilibrium

We raise it the constraint that a laborer doesn't participate in resolution the puzzle if its utility is negative. in this case the equilibrium in condition $\sum_k \ell_k^* \leq N$, with $\ell_k^* \geq 0$, for $k = 1, \dots, K$. this game referred to elastic game. then :

$$U_k(\ell_k) \begin{cases} p_k - \gamma_k, & \text{if } \ell_k > 0, \\ 0, & \text{otherwise.} \end{cases}$$

This game can be said to be an inelastic game as previously described. if the vector l meets the conditions then $(\exists k \mid l_k = N, l_k \geq 0, k = 1, \dots, K)$

or $\ell_0^* = 0$ in non elastic game then in condition k in each $l_k > 0$ then $U_k(l_k - 1) \geq U_k(l_k + 1)$.

Similar to the theory which has been demonstrated, which establishes the existence of the equilibria texts and their characteristics. This statement is the same evidence as before.

Remember that the theory of 1 i and j, $S_i = S_j$. $\ell_k^* = \sum_{i \in \mathcal{N}} 1_{S_i^* = k}$ this solution:

$$\operatorname{argmax}_{\ell} \sum_{k \in \mathcal{K}} \sum_{l=1}^{\ell_k} (p_k(l) - \gamma_k) \quad (24)$$

$$\text{subject to: } \sum_{k \in \mathcal{K}} \ell_k \leq N, \quad \ell_k \geq 0. \quad (25)$$

4.6 Non-Atomic Miners For The Multiple Esp's And Multiple Cryptocurrencies Game

We will now find the average median of gaming cryptocurrencies. This estimate is important for additional knowledge of ESP and game cryptocurrencies.

5. Wardrop Equilibrium Basics

5.1. Problem Formulation

We assume that the miners are non-atomic, in this case the given vector i will be solved by the miners as follows.

$$\max \left\{ \max_{k,m} \{ \mathcal{U}_{k,m}(\ell) \}, 0 \right\}, \quad (26)$$

where,

$$\mathcal{U}_{k,m}(\ell) = \frac{\mu_{k,m}}{\sum_{m'} \mu_{k,m'} \ell_{k,m'}} q_k \left(\sum_{m'} \mu_{k,m'} \ell_{k,m'} \right) - \gamma_{k,m}. \quad (27)$$

If the miners are atoms, the decision of each particular miners (assuming that the miners do not change their strategy) will have an effect on vector i , but the assumption that non-atoms are miners, the deviation will not change the value of the vector i , therefore it is a good thing. Then given $\operatorname{arg} \max$ (26). This assumption applies in two ways. First, when the miners realize that their decision will have a big impact on the utility of $u_k, m, (i)$ for all k and m . Second, when the number of miners is large, and YK, UK, M is small. Haurie and Marcotte (1985) found a non-atomic equilibrium, also known as Wardrop equilibrium. It is the insight of many equilibrium players under the diagonal concave conditions established by Rosen (1965) Altman et al. (2011, 2019). Shows that the same game in adjusting the complexity of the puzzle is $q_k = 1$. In this case, the miners do not take into account the impact of the decisions taken.

5.2 Equilibrium Characterization

below non atomic vektor i :

$$\mathcal{U}_{k,m}(\ell^*) = \mathcal{U}_{k'',m''}(\ell^*), \quad (28a)$$

$$\text{if } \ell_{k,m}^* > 0, \ell_{k'',m''}^* > 0, \forall m, m'', k, k'',$$

$$\mathcal{U}_{k,m}(\ell^*) \geq \mathcal{U}_{k'',m''}(\ell^*), \quad (28b)$$

$$\text{if } \ell_{k,m}^* > 0, \ell_{k'',m''}^* = 0, \forall m, m'', k, k'',$$

$$\mathcal{U}_{k,m}(\ell^*) \leq 0, \text{ if } \ell_{k,m}^* = 0, \forall m, k, \quad (28c)$$

$$\sum_{k,m} \ell_{k,m}^* \leq N. \quad (28d)$$

Before studying equilibria, we give reasons for the equation of (28a) - (28d). for in-depth analysis of non-atomic equilibria. we refer to Roughgarden (2005) and Wan (2012). can miners be attracted to deviate from i ? let $SA(i^*)$ be a set of (k, m) corresponding to the active miners.

$$SA(\ell^*) := \{(k, m) \mid \ell_{k,m}^* > 0, \ell_{k,m}^* \text{ solution of (28a) - (28d)}\}. \quad (29)$$

The equation of (28a) implies that for all $SA(I^*)$ the utility is the same. then if miners are interested in deviating from I^* , $\arg \max$ of (26) must be a pair $(k', m') \in / SA(I^*)$. However, an investment, say, in $(k', m') \in / SA(I^*)$, must be suboptimal according to (28b). Therefore, a miner will always choose $(k, m) \in SA(I^*)$, which naturally implies that I^* satisfying (28a)-(28d) is an equilibrium strategy. Knowing (28a) - (28d), we will provide some basic knowledge of equilibrium structure. for now we will assume that the equilibrium i always exists.

5.3 Miners Invest at Maximum in Two ESPs for a Given Cryptocurrency

Then we will show the following: DEFINITION 6. Two pairs of ESPs (m, m') and (m'', m''') , such that $\mu_{k,m} < \mu_{k,m'}$ and $\mu_{k,m''} < \mu_{k,m'''}$, are said to be colinear with respect to cryptocurrency k if:

$$\frac{\mu_{k,m} - \mu_{k,m'}}{\gamma_{k,m} - \gamma_{k,m'}} = \frac{\mu_{k,m''} - \mu_{k,m'''}}{\gamma_{k,m''} - \gamma_{k,m'''}}. \quad (30)$$

Intuitively, the two ESP pairs are collinear when the capacities and costs differ and are aligned linearly. here's a theory that establishes the structural outcome THEOREM 7. no ESP pair is collinear with the cryptocurrency k . then there is a mining equilibrium that invests a maximum of two ESPs for the crypto. Proof: let Proof be based on the argument of contradiction which we assume without losing its generality, that look on below:

$$\frac{\mu_{k,m} - \mu_{k,m'}}{\sum_n \mu_{k,n} \ell_{k,n}^*} q_k \left(\sum_n \mu_{k,n} \ell_{k,n}^* \right) = \gamma_{k,m} - \gamma_{k,m'} \quad (31)$$

$$\frac{\mu_{k,m} - \mu_{k,m''}}{\sum_n \mu_{k,n} \ell_{k,n}^*} q_k \left(\sum_{m'} \mu_{k,n} \ell_{k,n}^* \right) = \gamma_{k,m} - \gamma_{k,m''} \quad (32)$$

which leads to the following contradiction $\frac{\mu_{k,m} - \mu_{k,m''}}{\gamma_{k,m} - \gamma_{k,m''}} = \frac{\mu_{k,m} - \mu_{k,m'}}{\gamma_{k,m} - \gamma_{k,m'}}$, concluding the proof. $\square$

5.4 When Will Miners Invest in Only One ESP for a Given Cryptocurrency?

Furthermore, we will determine a condition which is good enough for miners in mining bitcoin in one ESP THEOREM 8. if there is a certain cryptocurrency, with the same ESP cost, then $(\gamma_k, m = \gamma_k, m')$ for all m, m' and if the rates are different, then $(\mu_k, m \neq \mu_k, m')$ for any $m \neq m'$, so (1) only one ESP is used and (2) the ESP used will have a high service level PROOF: we assume that for a particular Crypto, it is denoted by k . the cost of using ESP is the same $(\gamma_k, m = \gamma_k, m')$ for all m, m' and the levels of both service and ESP differ $(\mu_k, m \neq \mu_k, m')$ for all m, m' . furthermore that the element equilibrium I^* two elements I_k, m , and I_k, m' such that $I^* k, m > 0$ And element values from $I^* k, m' > 0$ for a pair of ESP (m, m') with (28a) $\mu_k, m = \mu_k, m'$ containing the argument (1). besides that, the miners invest in one ESP. The most widely used ESP will be the highest forgings. Consider theorems 7 and 8, show the median result, which is equivalent to conjecture four and theorem 3. as illustrated below.

5.5 Blockchain Mining Collapse

Next, we characterize conditions under which the mining costs preclude miners from investing their computational resources into the mining game.

DEFINITION 9. A given cryptocurrency k dies under equilibrium λ^* if $\lambda^*_{k,m} = 0$ for $1 \leq m \leq M$.
 Theory 10. If no ESP pair is Colinear related to k , then:

$$\max_{m: 1 \leq m \leq M} \left\{ \frac{q_k(\mu_{k,m}N)}{N} - \gamma_{k,m} \right\} < 0 \quad (33)$$

PROOF: Equations (28a)-(28d) imply that if :

$$\mathcal{U}_{k,m}(\ell) < 0, \text{ for all } m \in \{1, \dots, M\} \text{ and } \ell \text{ such that } \sum_m \ell_{k,m} \leq N \quad (34)$$

then cryptocurrency k dies. Condition (34) is satisfied if:

$$\max_m \left\{ \max_{\sum_{m'} \ell_{k,m'} \leq N} \mathcal{U}_{k,m}(\ell) \right\} < 0. \quad (35)$$

Next, we further characterize the solution of the fractional pseudo-concave optimization problem:

$$\max_{\sum_{m'} \ell_{k,m'} \leq N} \mathcal{U}_{k,m}(\ell) \quad (36)$$

the results of the above conclude that:

$$\begin{aligned} & \mu_{k,m'} q_k \left(\sum_{m''} \mu_{k,m''} \ell_{k,m''}^*(k, m') \right) \\ &= \lambda(k, m'), \text{ if } \ell_{k,m''}^*(k, m') > 0, \end{aligned} \quad (37)$$

$$\begin{aligned} & \mu_{k,m} q_k \left(\sum_{m''} \mu_{k,m''} \ell_{k,m''}^*(k, m') \right) \\ &\leq \lambda(k, m'), \text{ if } \ell_{k,m''}^*(k, m') = 0. \end{aligned} \quad (38)$$

equations of (37) and (38) with the fact that the two ESP pairs associated with K tell us that the optimal load is given to

$$\ell_{k,m'}^*(k, m') = \begin{cases} N, & \text{if } m'' = m' \\ 0, & \text{otherwise.} \end{cases} \quad (39)$$

Therefore, $\mathcal{U}_{k,m'}(\ell^*(k, m')) = \frac{q_k(\mu_{k,m'}N)}{N} - \gamma_{k,m'}$, which together with (35) concludes the proof. $\square$

Then we have considered the most extreme scenario, where the miners do not have profit from existing crypto mining. Definition 11. Mining Blockchain Collapses when any cryptocurrency dies. COROLLARY 12. If, for each k , there are no two pairs of ESPs that are colinear with respect to cryptocurrency k , and if for all m and k , then blockchain mining collapses. Note that there exists an N such that for every $N > N$ the condition above is satisfied. Moreover, if $N\gamma_{k,m} > 1$ for all k and m , the condition above also holds. Then blockchain mining collapses. Note that there exists an N such that for every $N > N$ the condition above is satisfied. Moreover, if $N\gamma_{k,m} > 1$ for all k and m , the condition above also holds. Then blockchain mining collapses. Note that there exists an N such that for every $N > N$ the condition above is satisfied. Moreover, if $N\gamma_{k,m} > 1$ for all k and m , the condition above also holds

$$1 - \exp(-T_k \mu_{k,m} N) - N\gamma_{k,m} < 0, \quad (40)$$

PROOF: The proof follows directly from Theorem 10. Indeed, blockchain mining collapses if:

$$\max_m \left\{ \frac{q_k(\mu_{k,m}N)}{N} - \gamma_{k,m} \right\} < 0, \forall k. \quad (41)$$

The condition above is equivalent to:

$$\frac{q_k(\mu_{k,m}N)}{N} - \gamma_{k,m} < 0, \forall (m, k), \quad (42)$$

which concludes the proof. $\square$

5.6 Existence and Uniqueness of Equilibrium

Regarding the existence of equilibrium as well as its uniqueness, we will limit the scenario where for each cryptocurrency k , the baia in all ESP is the same, ($\gamma_k, m = \gamma_k, m'$ for all m, m') and the service rate is different ($\mu_k, m \neq \mu_k, m'$ for all m, m'). as is known in theorem 8, for every crypto, at most one ESP will be actively mined. $m(k) = \max_m \mu_k, m'$. ESP $m(k)$ the only candidate used for crypto mining, therefore it is seen from the equilibrium conditions (28a) - (28d) to

$$\mathcal{U}_{k,m(k)}(\ell^*) = \mathcal{U}_{k'',m(k'')}(\ell^*), \quad (43a)$$

$$\text{if } \ell_{k,m(k)}^* > 0, \ell_{k'',m(k'')}^* > 0, \forall k, k'',$$

$$\mathcal{U}_{k,m(k)}(\ell^*) \geq \mathcal{U}_{k'',m(k'')}(\ell^*), \quad (43b)$$

$$\text{if } \ell_{k,m(k)}^* > 0, \ell_{k'',m(k'')}^* = 0, \forall k, k'',$$

$$\mathcal{U}_{k,m(k)}(\ell^*) \leq 0, \quad (43c)$$

$$\text{if } \ell_{k,m(k)}^* = 0, \forall k,$$

$$\sum_k \ell_{k,m(k)}^* \leq N. \quad (43d)$$

Theory 13. Non-Atomic Games under the symmetrical charge discussed, at most receive more than one interior equilibrium which is the solution of the following optimization:

$$\operatorname{argmax} \sum_{k=1}^K \int_{\epsilon}^{\ell_{k,m(k)}} \frac{q_k(\mu_{k,m(k)} x)}{x} dx - \gamma_k \ell_{k,m(k)}, \quad (44)$$

$$\text{subject to } \sum_k \ell_{k,m(k)} \leq N, \quad \ell_{k,m(k)} \geq \epsilon \quad (45)$$

PROOF: see and note that if there is a solution to the problem interior (44) - (45). if each load is truly greater than 0, then the optimization conditions are proposed and given by (43a) - (43d) which gives one-to-one correspondence between the solutions to the optimization problem. In addition, note that for all k and m , $q_k(\mu_{k,m(k)} | \ell_{k,m(k)})$ is $\ell_{k,m(k)}$ a decreasing function in $\ell_{k,m(k)} > 0$. Therefore the function $\int \ell_{k,m(k)} q_k(\mu_{k,m(k)} x) dx - \gamma_k \ell_{k,m(k)}$ is strictly concave and the q_k optimization problem posed above has a unique solution, as all the functions are strictly concave.

5.7 Parallel Computations: Auctions And Continuous Actions

The models known so far assume that the puzzles that the miners solve will be sent to the rest of the ESP. In this section we consider games in which each miners can choose how much to bid for the computing power proposed by ESP. We assume in this section with $q_k = 1$. according to the fine grained adjustment of puzzle complexity. and also the one-to-one correspondence between miners and ESP, i.e., i.e., $K = 1$. Then, $l^*, m = 1$ for $m = 1, \dots, M$. suppose x_m denotes the bid value of the miners according to the ESP, but we have a minimum constraint $x_m \geq q$ for all m . we also assume that the ESP service level demanded by miners m , μ^*, m , equals m , x_m , i.e., μ^*, m , then (2).

$$\eta = \sum_{j=1}^M x_j. \quad (46)$$

6. Basic Model

$$P_m = \frac{x_m}{\eta} = \frac{x_m}{\sum_{j=1}^M x_j}, \quad (47)$$

Which is the miner *expected gain* that can be contrasted against (6). The total cost for miner m is $x_m\gamma$, where γ is a constant. The utility for player m is thus:

$$U_m(x) = \frac{x_m}{\sum_{j=1}^M x_j} - x_m\gamma. \quad (48)$$

This Following Unconstrained Game :

$$\text{UNCONSTRAINED GAME: } \max_{x_m} \frac{x_m}{\sum_{i=1}^M x_i} - x_m\gamma \quad (49)$$

The main result in this section is Unconstrained Game. Theory 14, for everything that gets a positive, γ -value, the game above has the uniqueness of Nash equilibrium and U is concave in x_m . PROOF: this is in accordance with Altman et al. (2016) who used a modification of the diagonal strict concavity properly. This game is presented and widely known by Dimitri (2017). Here we will explain the results of Dimitri (2017).

5.8 Normalized Equilibrium: Physical Bounds on Resources and Shadow Prices

We will look at the extent of the constraints involving orthogonal. That is, the actions that can be used for miners also affect other miners. Furthermore, formally introduce limits of capacity.

$$\text{CONSTRAINED GAME: } \max_{x_m} \frac{x_m}{\sum_{i=1}^M x_i} \quad (50)$$

$$\sum_{j=1}^M x_j \leq V \quad (51)$$

Note, in the game above, we assume that each player will maximize the probability of being the first. and below the total limit bid by all players. considering the amount bid must be proportional to the amount of resources invested by the player [42]. Limits of capacity can represent limits on resources. let γ be the equilibrium of the Constrained Game. let $\gamma [-m]$ show the factor of all miners except m , such as in below :

$$\mathcal{L}_m(y_m) = \frac{y_m}{\sum_{j=1}^M y_j} - \lambda_m(y_{[-m]}) \left(\sum_{j=1}^M y_j - V \right) \quad (52)$$

and

$$\lambda_m(y_{[-m]}) \left(\sum_{j=1}^M y_j - V \right) = 0. \quad (53)$$

The last condition above is called complementarity. We call the game a utility provided by the Lagrangians $\mathcal{L}_m$ as the relaxed game:

$$\text{GENERAL RELAXED GAME:} \quad (54)$$

$$\max_{x_m} \mathcal{L}_m(x_m) = \frac{x_m}{x_m + \sum_{j=1, j \neq m}^M y_j} - \lambda_m(y_{[-m]}) \left(x_m + \sum_{j=1, j \neq m}^M y_j - V \right) \quad (55)$$

This version will be a part to prove the properties of the constrained game [43].

6. Discussion

Positive and Negative Externalities. In the proposed model, we assume that the contribution to the system with minor results in negative externality on the other miners. of course, the reasons for the competition are the basis of the mining process. by including more blockchain miners will be stronger [44]. This value in updating will translate into an increase in crypto value [45] [46] therefore as the number of miners increases, each miner can contribute to the system [47]. **Mining Pools:** Mining the key pool of the current blockchain system [48], the competition that occurs is analyzed in this paper. And it also applies to mining pools, and two scenarios occur. First, the perspective of a collection of miners, it can use resources for mining purposes,

Figure 6. Bitcoin hash rate distribution

In the 6th picture, there is an illustration of the rate of bitcoin as of 24 October 2019. mostly from 4 miners. According to the 4th and the 7th theorem, only two mining pools have a role in the network. This may occur because of instability. Look at it and notice that the model

that has been designed only considers the miners' positive results. (Appendix A) that positive result can motivate miners.

Medium from multi-cryptocurrency. In its ecosystem, the big miners usually make decisions dynamically. The decision is based on the value of cryptocurrency and the cost of mining itself. The power of computing across the network is the source of voting, and several mechanisms were developed to hold multiple miners across platforms (Ulrich, 2017). one of the mechanisms is EDA. Refers to an emergency difficulty adjustment, which reduces the difficulty when there are not many miners around. preventing that blockchain from dying.

Puzzle complexity In bitcoin, the computational difficulty level is adjusted dynamically so that it takes time to mine a block and varies between predetermined time limits. Bitcoin blocking rate is 10 minutes, theoretically. The number of adjustments to the puzzle complexity generates bitcoins, regardless of the number of miners. An increase in the number of miners impacts how long mining time is required per block (Meshkov et al., 2017; Wisdom, 2018). In Huberman et al. (2017), adjusting the frequency with which the block is the congestion in the network.

Users fees Users pay a fee for their block to be mined, and this fee has an impact on competition among miners because this serves as a draw or a reward in this mining. The higher the cost the miners offer. The greater the amount that can be. in this writing. We still haven't calculated the role of each blockchain user. We illustrate that the interaction of each user has an impact on such complex dynamics.

7. Conclusion

The competition between miners is at the heart of the blockchain itself. Competition is an essential element that makes miners always try to reach consensus. We gave examples of some ESPs and even more, which characterize some of these cryptocurrencies as non-cooperative games [49]. Then for the results of several players, we give the property of equilibration. By leveraging the results from the congestion game, we have defined Nash Equilibrium and an efficient algorithm we believe that these can open much work in the future. We do not take into account strategic decisions regarding penalties and cooperation between miners. The game naturally arises from the sequential solution that comes from multiple puzzles.

8. Acknowledgments

The author would like to thank Raharja University, the lecturers who helped, and friends who always motivated us. Furthermore, do not forget to Alphabet Incubator, who has facilitated a place to support and provide a place to do this research.

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