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Crafting performance-based cryptocurrency mining strategies using a hybrid analytics approach

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ABSTRACT

Crafting and executing the best cryptocurrency mining strategy is vital to succeeding in cryptocurrency market investments. This study aims to identify the best cryptocurrency mining strategy based on service providers' performance for cryptocurrency mining using a hybrid analytics approach, which integrates the Analytic Hierarchy Process (AHP) and Fuzzy-TOPSIS techniques, along with sensitivity analysis. The results show that hosted mining is the overall best cryptocurrency mining strategy, followed by home mining and cloud mining, based on both total cost of operations and cryptocurrency payout criteria. The empirical findings also suggest that the critical features of the highest performing service providers (i.e., hosted mining strategies and cloud mining) were their flexibility of contracts and the superior efficiency in terms of the daily payout. Finally, of the three location alternatives for home mining, Turkey ranks first compared to the U.S. and Europe.

1. Introduction

Bitcoin (BTC), often described as a cryptocurrency, is a groundbreaking digital asset today as a mining process reward. Since the release of Nakamoto Satoshi's seminal paper in 2008 on the creation of BTC as a peer-to-peer (P2P) electronic cash system, BTC has increasingly become the leading cryptocurrency worldwide. One may define BTC as a reward of a process known as mining. It merely relies on a decentralized system of transactions verified by cryptography network nodes and recorded in a distributed ledger called blockchain [46]. Anyone can trade it in over-the-counter markets or use it as a medium of exchange for other cryptocurrencies, products, or services.

In the beginning, BTC mining was the best way for programmers to acquire the cheapest BTCs in the blockchain. BTC became popular after its peak level of USD 19,783, reaching a market capitalization of USD 332 billion for 17.8 million BTCs as of December 2017. This rising popularity has led to various mining strategies rather than directly purchasing a BTC from cryptocurrency markets. The massive discrepancy between purchasing a BTC and average mining cost has also attracted individual investors from various backgrounds to choose the best possible alternative cryptocurrency mining strategies ranging from home mining to cloud and hosted mining.

This unprecedented increase in the popularity of cryptocurrencies has also led to growing scholarly attention in various fields. Early studies mostly concentrated on the technical side of cryptocurrencies involving the efficiency of their operating mechanisms [22,28,38]. Recently, there is a burgeoning research interest focusing on the economic and financial aspects of cryptocurrencies. These studies predominantly investigated the potential nexus between BTC price volatility and trading mechanism [1,4,5,23,27,36,47]. Some researchers studying the BTC price volatility assert that BTC leads to reoccurring bubble behavior [24,38,48], while others acknowledge the BTC as an innovative financial tool [25,26,49].

Additionally, several studies investigated the association of risk and returned to diversified portfolios, including cryptocurrencies. These studies claim that cryptocurrencies in portfolio investments offer an alternative with high return and low correlation with other financial assets, while others state that the inclusion of BTC reduces portfolio risk. Portfolio diversification across different cryptocurrencies may also improve investment performance [26,31,32,39,55]. Nonetheless, some authors argue that BTC is not a safe haven and offers no hedging capabilities [14,35].

Despite these studies, there is still a gap in the literature on the

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availability of innovative business analytics tools for determining the best cryptocurrency mining strategy as well as selecting the best performing service provider for cryptocurrency mining. In fact, no significant research has hitherto been reported that examines the effect of cryptocurrency mining strategy on portfolio risk-return tradeoff.

Using a hybrid analytics approach based on a multi-criteria decision-making (MCDM) technique, this study aims to examine cryptocurrency mining strategies and evaluate the performance of cryptocurrency mining service providers. It essentially seeks to answer the following exploratory research questions: (1) What are the leading cryptocurrency mining strategies available for investors? (2) How do cryptocurrency mining service providers using a particular mining strategy (i.e., cloud mining or hosted mining strategy) vary based on their performance with respect to the following criteria: daily payout, maintenance cost management, option diversity, pool allocation, and hashing power management? (3) Does the location choice for cryptocurrency mining strategy affect investment decisions? (4) Which is the most preferred cryptocurrency mining strategy based on payout performance and cost-efficiency?

Relying on extensive secondary data analysis and in-depth interviews with selected subject matter experts, we use two analytics-based MCDM techniques jointly, including the Analytic Hierarchy Process (AHP) and the Technique for Order of Preference by Similarity to Ideal Solutions (TOPSIS) methods, within a fuzzy environment. Sensitivity analysis has also been carried out to validate the result of our proposed methodology. AHP, one pf the most matured MCDM methods, is still being widely used as a robust method when deciding among a complex set of criteria and alternatives presented in a quantitative and qualitative dataset [29]. Similarly, Fuzzy-TOPSIS has also been proven to be a powerful tool for dealing with uncertainty and ambiguity. It is a well-adjusted technique to handle distinct decision-making processes as decision-makers' preferences are affected by multiple attributes that feature both qualitative and quantitative aspects. Thus, adopting this hybrid analytics methodology along with using sensitivity analysis on this new application domain provides a more robust and evidence-based approach for accurate and timely decision-making in cryptocurrency mining and serves as a useful contribution to the existing body of research and practice in decision support systems.

The rest of this paper is structured as follows. Section 2 provides the conceptual background and reviews the most relevant literature. Sections 3 and 4 present the methodology and application of the proposed model. Section 5 presents and discusses the results, and finally, the last section, Section 6, provides the summary and concludes the paper.

2. Literature review

This section provides background literature on the emerging trend in cryptocurrency mining and its ecosystem.

2.1. The emerging trend of cryptocurrency mining

Among nearly 5000 cryptocurrencies traded worldwide at present, the BTC has become the most popular cryptocurrency. According to recent data released by CoinMarketCap (2020), the BTC accounts for over 85% of the overall cryptocurrency market, whose capitalization reaches more than USD 200 billion.

Since its first launch on the market, purchasing a BTC in a deregulated market was easy and cheap. Then, sharp increases in the price of BTC along with other cryptocurrencies since mid-2017 have stimulated investors to be deeply interested in trading as well as mining cryptocurrencies. For most of the cryptocurrency investors, cloud mining appeared to be an up-and-coming method of acquiring cryptocurrency due to its low maintenance costs, user-friendliness, and technical support availability.

However, many investors purchased cloud mining contracts from some fictitious companies operating on the web in deregulated cryptocurrency mining markets. They ended up losing their investments. These *Ponzi scheme* cases instigated social media companies like Facebook and Instagram to ban cryptocurrency mining advertisements. Nevertheless, there are still high-performing cloud mining service providers that offer high-quality services.

Due to the growing lack of trust in cloud mining service providers, some individual investors began to mine cryptocurrencies at home by acquiring the required hardware and utilities, known as home mining. However, these individual investors had to cope with the hashing difficulty of cryptocurrency mining by either extending the existing hardware or switching to high-tech miners, leading to more cooling and energy consumption. Moreover, some individual investors expanded their home mining operations into mining farms with more investment in technology infrastructure and utilities to increase cryptocurrency mining capacity.

In addition to cloud mining and home mining, some professional investors have preferred a third method, so-called hosted mining, due to its relative advantages. It is widely acknowledged that this method provides investors with extra flexibility to control miners in the service provider's mining facilities compared to cloud mining. Instead, the hosted mining service provider covers all operating expenses and provides technical assistance to the tenant for maintenance management. Other striking advantages of hosted mining are its provision of pool membership fee advantages and allowing access to cutting edge miner technologies listed by cryptocurrency miner producers.

2.2. Cryptocurrency mining ecosystem

The extant literature suffers from a paucity of research linking cryptocurrency mining strategies with cryptocurrency investment or portfolio diversification process. Previous studies mainly focus on the BTC operating mechanism, cryptocurrency price prediction, hedging, and portfolio diversification with BTCs.

To simplify the process of cryptocurrency mining, we first provide a background for BTC. As introduced by Satoshi [46], the BTC functions as a peer-to-peer electronic cash system operating on a cryptographic protocol without any central authority. BTC is mined and carried out collectively by the network (i.e., open-source). It is sufficient to have a decentralized network of computers to record digitally signed transactions.

BTC is created as a reward of a process known as "mining" by using a protocol called "proof-of-work system." It is a mechanism deterring denial-of-service attacks checking processing time by a computer. This peer-to-peer network forms a distributed timestamp server [6,20]. The mining process involves block creation as hashed with SHA-256, which is a set of cryptographic hash functions. As the hashing produces valid results, blocks are chained. If blocks are generated too quickly, the difficulty increases and more hashes are required to make a block and generate new BTCs [6].

BTC mining has been increasingly becoming more challenging and costlier as new payouts are provided to miners. Therefore, miners should deal with the increasing hashing difficulty by investing in new CPU powers. Subsequently, BTC mining becomes attractive as the BTC price is above the total investment and operating costs for contributors in the network.

There are numerous studies on cryptocurrency mining that are mostly related to technical aspects of blockchain technologies and their operating mechanisms, which revolve around the following key areas: cryptovirology, cybersecurity, energy efficiency, optimization of mining algorithms, cryptocurrency mining scripts, cryptocurrency mining malware system, detection of covert cryptocurrency mining, mobile mining, crypto-jacking, pricing of mining ASICs, and other blockchain topics. To exemplify, Kim [33] examined the BTC mining system's efficiency by developing a Multi-Leader Multi-Follower Stackelberg Game Model using system parameters, including BTC rewards, mining difficulty, transaction, discount, and pooling fee. He concluded that through

Table 1
A summary of the studies on cryptocurrency mining ecosystem.

Author (Date)	Subject	Methods/Analysis	Components	Findings
Satoshi [46]	BTC	A model proposal as a solution to the double-spending problem using a peer-to-peer network	Network timestamps transactions by hashing, ongoing chain of hash-based proof-of-work, forming records	A Peer-to-Peer Electronic Cash System, (i) as a system for electronic transactions without relying on trust, (ii) a peer-to-peer network using proof-of-work to record a public history of transactions.
Cocco & Marchesi [12]	Economic mining	The agent-based artificial market model of the BTC mining process	Mining hardware performance; Price, hash rate, power consumption, price	Some key stylized facts of BTC real price series and the BTC market are very well reproduced. Specifically, the model reproduces quite well the unit-root property of the price series, the fat tail phenomenon, the volatility clustering of the price returns, the generation of BTCs, the hashing capability, the power consumption, and the hardware and electricity expenses incurred by Miners.
Dilek and Furuncu [16]	BTC mining and environmental effects	Historical data analysis	Energy consumption, BTC Mining Level	Energy consumed as a result of increased BTC mining will have environmental and social consequences, such as global warming and climate change
Haghighat & Shajari [28]	BTC mining pools	Reinforcement learning method	BTC mining, mining pools, computation power	Launching a block withholding attack, some pools had the potential to reach the majority (51%) of the total computational power of the network with much lower initial computational power (with less than 25% of total computation power of the network.
Easley et al. [22]	Evolution of BTC transaction from mining to markets	Regression analysis, Game-theoretic model	Mining rewards, transaction fees, waiting time	(i) waiting time becomes large, users exit the blockchain in much the way that miners exit the blockchain when their revenues no longer generate profits. (ii) the equilibrium in the BTC blockchain is a complex balancing of user and miner participation, (iii) as the BTC ecology migrates to a more market-based system, a variety of interesting issues become apparent, (iv) while constraints limiting the growth of new BTC issuance are in line with the system's original design, the constraints on block size are a relatively recent addition intended to decrease the system's vulnerability to attack
Li et al. [38]	Ranking BTC transactions in mining	GSP auction model	BTC transaction components: Size, fee, input/output amount, address, time	(i) the influences of quality scores and virtual fees on users' equilibrium decisions and payoffs are investigated, and some interesting properties are obtained, (ii) research has confirmed the superiority of the GSP mechanism on saving users' fees, compared with the currently adopted GFP mechanism
Kim [34]	BTC popularity	Historical financial data set analysis	BTC transaction components: Size, fee, input/output amount, address, time	BTC's popularity evolves across time depending on price and mining cost.
Delgado-Mohatar et al. [15]	BTC mining and its profitability	BTC financial data analysis using QUANDL database	BTC mining, variable costs, BTC price, system sustainability	BTC production (Mining) cost evolves across time. The marginal cost linked to Electricity Prices and the hashing. BTC mining is no longer profitable for miners whose electricity costs are above 0.14 $/kWh due to their prices falling below the marginal cost threshold.
Biryukov & Tikhomirov [7]	Cryptocurrency wallet security and privacy	Static analysis and transaction clustering	BTC, Dash, Monero, and Zcash Wallet	(i) moderately resourceful attackers can correlate transactions issued from one device with relatively high accuracy, (ii) a global passive adversary can cluster transactions issued from one device within a short time frame with relatively high accuracy.
Veselý & Žádník [54]	Cryptocurrency mining detection	Passive-active flow monitoring and sMaSheD catalog	Pooled mining process	Mining detection could be possible using the sMaSheD system and two approaches.
Panagiotidis et al. [41]	BTC return prediction	GSADF, PC-LASSO, Rolling window PC-LASSO, FLS	Potential drivers of BTC returns for the period 2010–2018	Economic uncertainty and stock market volatility are among the most important variables for BTC. The study also traces strong evidence of bubbly BTC behavior in the 2017–2018 period.
Martínez et al. [40]	Cryptographic tools for BTC	A review of cryptographic tools	Cryptographic tools for BTC and blockchain	The main cryptographic tools related to the security and reliability of blockchain are presented: hash functions, digital signatures, elliptic curves, and Merkle trees
Das & Dutta [13]	BTC mining and energy consumption	Regression analysis	Energy consumption and miner's revenue	(i) the negative association between energy consumption and miner's revenue; (ii) the negative impact is strongly significant when the miner's revenues are low and volatile, (iii) the higher energy consumption in the wake of escalating global energy costs amid bearish market sentiments impedes the miners to break-even. Hence, it would not be viable to sustain the business unless it relies on cheap energy sources and efficient mining hardware.

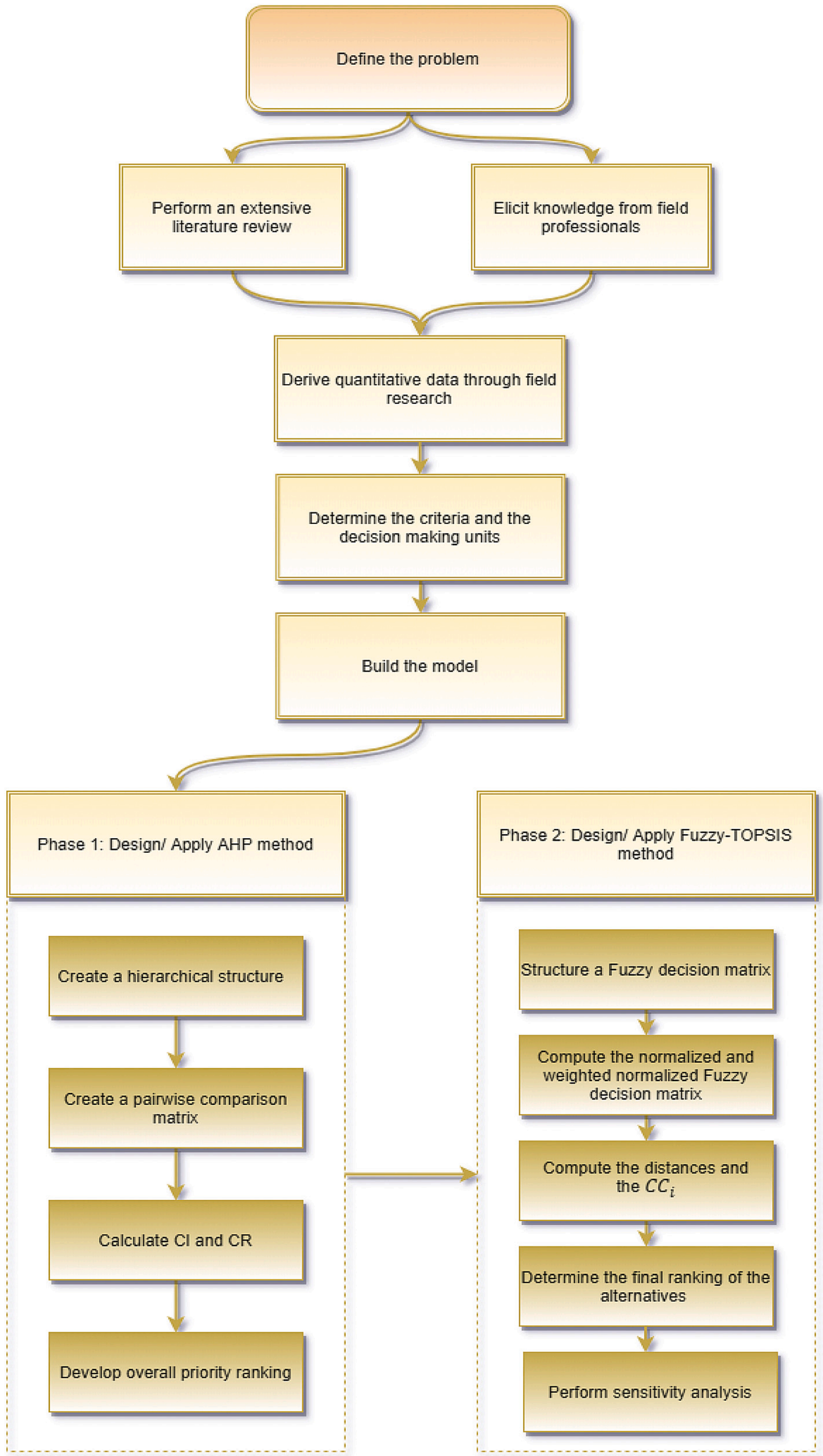

Fig. 1. A flowchart of the proposed research methodology.

system-level simulations, the game approach outperformed the existing BTC schemes in providing a better fair-efficient system performance. In a more recent study, Haghighat and Shajari [28] examined BTC mining pools and addressed the potential risk of reaching the majority of the total computational power of the network (51%) with lower hashing power. Easley et al. [22] evaluated the BTC transactions from mining to markets in a similar vein by developing a game-theoretic model. They noted that the equilibrium in BTC blockchain is a tricky balancing of user and miner participation and imbalances between member pool inflow and outflow, potentially leading to instability in the blockchain. Table 1 provides an extended list of previous studies on the cryptocurrency mining ecosystem.

3. Methodology

This study aims to craft effective cryptocurrency mining strategies using a hybrid analytics model. We rank alternatives for mining services to select the best option using the MCDM approach in a fuzzy environment. Our model is based on the integrated use of AHP and Fuzzy-TOPSIS methods and comprises two main phases: (i) the computation of weighted criteria by the AHP and (ii) the identification of the exact order for listing alternatives with Fuzzy-TOPSIS and verification by using sensitivity analysis. Fig. 1 delineates a flowchart of our proposed hybrid model for the best cryptocurrency mining strategy.

AHP, developed as an MCDM problem-solving method by Saaty [44], helps figure out the best alternative among many [8]. This nonlinear procedure is carried out by breaking the MCDM problem into a hierarchical structure. The goal takes place at the top of the hierarchy, followed by the criteria, the sub-criteria, and the alternatives. This makes it easy to analyze each level and then rank the alternatives at the end of the hierarchical tree.

Although many researchers have been applying the Fuzzy-AHP method, which is a synthetic extension of the AHP method due to its coverage for the uncertainty in expert opinions [3,17,18,37,42], there is no consensus on the superiority of the Fuzzy-AHP technique over conventional AHP in terms of the quality of solutions [9]. AHP has several advantages with respect to addressing complex problems. First, it helps determine the best course of action based on the most important criteria combining the tangible and intangible characteristics of queries in a systematic way [21]. Secondly, it allows measuring the consistency of decision-makers while comparing their judgments. This consistency is one of the key features that distinguishes AHP from the other MCDM techniques and provides rationality to the method [2]. AHP also reduces subjectivity and bias in the decision-making process [19]. Finally, AHP heavily relies on experts' judgments when deriving priority scales, making it easy to adjust and re-scale the pairwise comparison matrices when needed [45,53]. The details of the calculation steps for AHP can be found in Saaty [44].

The Fuzzy-TOPSIS technique has been developed after integrating fuzzy logic [57,58] to traditional TOPSIS [10,30] to handle fuzziness, imprecision, and the lack of information [43]. Its conceptual process is based on producing an exact preference order among the alternatives by identifying the optimal solution with the shortest Euclidean distance from the positive ideal solution and the farthest Euclidean distance from the negative ideal solution (please see Chen and Hwang [11] and Wei and Zhou [56] for the procedural steps of the Fuzzy-TOPSIS in detail).

4. Application of the proposed model

In our hybrid analytics technique, we designed the AHP method to determine the best cryptocurrency mining service provider for each of the cloud mining and hosted mining strategies. Using this technique, we also identified the best location for the home mining strategy. Then, we applied the Fuzzy-TOPSIS method to select the best cryptocurrency mining strategy after determining the three cryptocurrency mining strategies' ranking. Finally, the results of the Fuzzy-TOPSIS were validated by running the sensitivity analysis.

4.1. Data

To conduct our application, we first carried out an extensive literature review to identify the cryptocurrency mining ecosystem components. We then gathered qualitative data to identify the selection criteria and alternatives for currency mining strategies and determine the best course of action. To this end, in-depth interviews were conducted with five selected cryptocurrency mining professionals having a background in computer science, blockchain, and information systems with at least two years of currency mining experience. These interviews provided us with useful insights into a deeper understanding of the cryptocurrency mining ecosystem. We also obtained some guidance on how cryptocurrency mining service providers operate and how they differ in terms of their service features.

We selected nine companies for cloud mining (CM1 to CM9) and four companies (HM1 to HM4) for a hosted mining strategy, based on their scores on Google user comments and positive feedback on web forums as cryptocurrency mining companies are not regulated by a central authority. Appendices 1 and 2 provide detailed information about service features and contract options of these cryptocurrency mining service providers that implement cloud mining and hosted mining strategies, respectively.

To investigate the effect of location choice of home mining strategy on cryptocurrency mining investment decisions, we selected three home mining location alternatives: the U.S., Europe, and Turkey. Both the U.S. and Europe represent developed countries, while Turkey signifies emerging market economies. These two groups of countries are envisaged to display some apparent differences in cost structure and access to the required technologies. Turkey serves as an appropriate country setting to represent emerging economies due to its massive market potential and its close resemblance to many other emerging market economies in terms of the industrial and institutional environment [51]. In addition, both availability and ease of access to reliable country-level data for home mining has made the selection of Turkey plausible among several other big emerging economies. According to a recent poll conducted by *Statista* [50], Turkey features as the pronounced leader among the individual countries in terms of cryptocurrency adoption and use of digital assets. Appendix 3 provides information about the cost structure of these three locations for home mining strategy in terms of the following criteria: the average rent m^2/month, cooling cost m^2/h, and electricity cost kW/h [50,52].

Table 2
Criteria set for the three cryptocurrency mining strategies.

Mining strategy	Criteria	Clarification
Cloud (Contract) mining	C1	The algorithm used by the service provider during the mining process
	C2	The minimum hash rate allowed to purchase by the service provider
	C3	The price of the contract
	C4	The maintenance cost given in the contract terms
	C5	The kind of hardware used during the mining process
	C6	The contract length is given by the service provider
	C7	The minimum withdrawal amount allowed in a month by the service provider
	C8	The mining diversity in the cryptocurrency allowed by the service provider
Hosted mining	C1	Contract length specified by the service provider
	C2	System installation fee
	C3	System yearly cost
	C4	Option diversity is given by the service provider
Home mining	C1	Cost of equipment needed for mining
	C2	Rent
	C3	Heating
	C4	Electricity

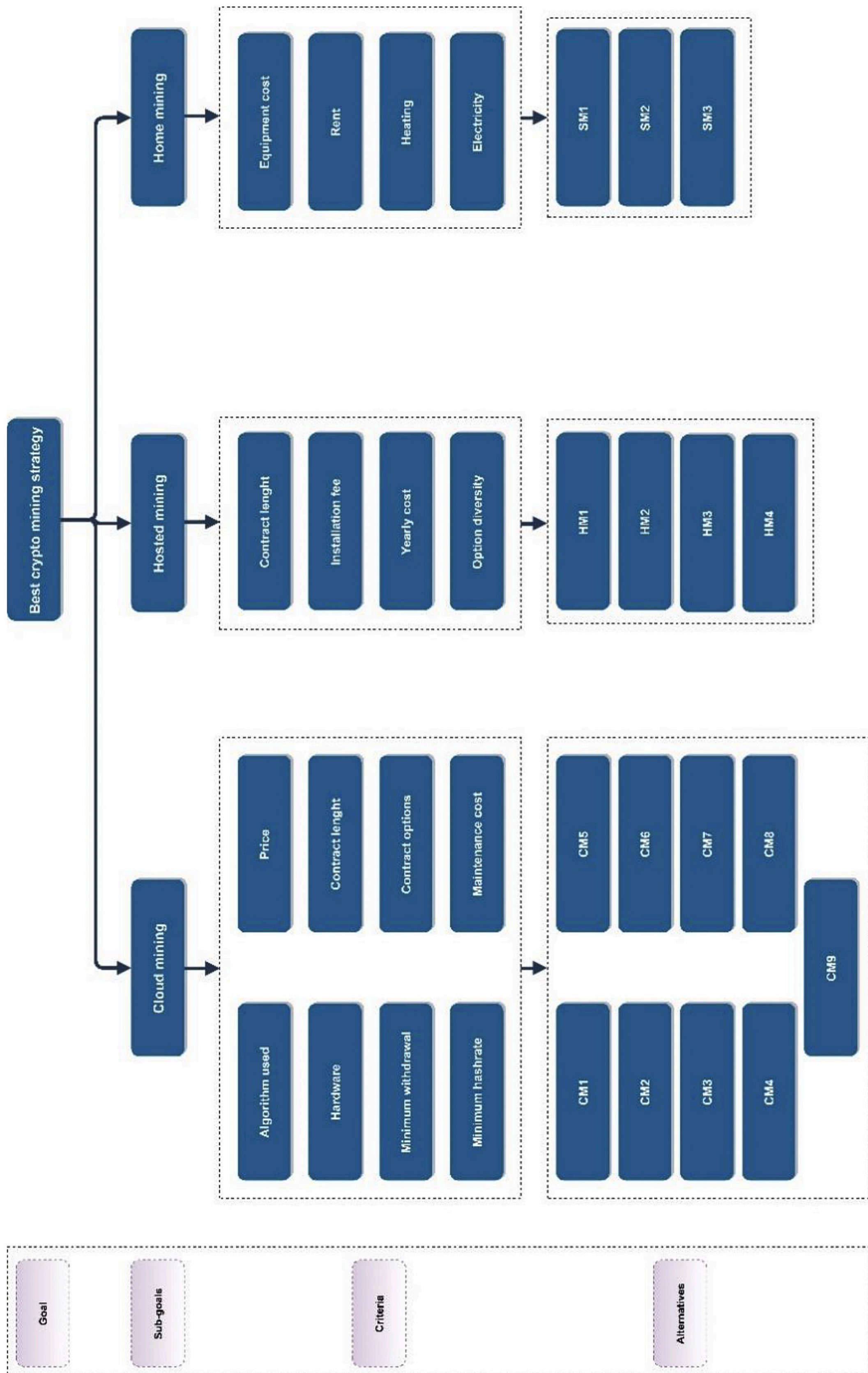

Fig. 2. Decision hierarchy for cryptocurrency mining strategy selection.

We amassed the quantitative data in two stages. The first stage involved the collection of data from the web pages of selected cryptocurrency mining companies, including contract options and service features. In the second stage, we acquired the data on cryptocurrency market price and mining conditions from blockchain.org and some leading cryptocurrency exchanges, including Bitfinex and Coinbase. The time frame of the data ranged between 15 October 2019 and 15 February 2020, where the price of the leading cryptocurrency, BTC, was fluctuating between USD 10,497 and USD 4016.

Table 2 shows the definition of the selected criteria for the strategies. The principal selection criteria for mining strategy in our model rely on its source of attraction for mining investors and portfolio managers who may tend to add a BTC to diversify their portfolios by using the mining process. In the final stage, we apply the hybrid model.

4.2. Empirical findings

Fig. 2 delineates our decision hierarchy for cryptocurrency mining strategy selection, which summarizes the goal, sub-goals, criteria, sub-criteria, and alternatives.

Following the deliberations with our selected experts on cryptocurrency mining, we determined eight cloud-mining criteria and nine cloud-mining service providers. Tables 3 and 4 present the criteria and their pairwise comparison matrix, respectively. The sum of each value was then calculated.

Next, we calculated the normalized pairwise matrix and the criteria weights. The normalized pairwise matrix was computed, where all the column elements are divided by the sum of the column. Then, the criteria weights were computed by taking the average of each row. Table 5 shows the values of the normalized pairwise matrix and the criteria weights.

Then, we computed the consistency of the calculated values in the normalized pairwise matrix by first multiplying the sum values with the criteria weights. Finally, we calculated the CI, and the C.R. Table 6 indicates the multiplication of the sum values and criteria weights.

λ_{max} is the sum of the (Sum* C.W.) from Table 6. That is:

$$\lambda_{max} = \sum (Sum*CW) = 8.85$$

CI = (8.85–8)/(8–1) = 0.12

As we have $n = 8$,

RI = 1.41 and finally,

$$CR \frac{CI}{RI} = 0.12 \Big/ 1.41 = 0.09$$

The CI is equal to 0.12, and the C.R. is less than 0.1, which is the upper bound limit for C.R. acceptance. Hence, the relative weights obtained utilizing the pairwise comparison matrix are consistent in our application.

After obtaining the C.R. ratios for each criterion, we determined a global score for each cryptocurrency service provider (CM1–CM9) and a consequent ranking using the AHP hybrid model. For each given attribute, we compared the importance of the alternatives. The same methodology is employed to rank the best service provider under cloud mining, hosted mining, and home mining.

Table 3
Criteria for the evaluation of cloud mining service providers.

Attribute	Clarification
C1	The algorithm used by the service provider during the mining process
C2	The minimum hash rate allowed to purchase by the service provider
C3	Price of the contract
C4	Maintenance cost in the contract
C5	Hardware used during the mining process
C6	Contract length
C7	Minimum withdrawal amount allowed in a month by the service provider
C8	Mining diversity in the cryptocurrency allowed by the service provider

Table 4
Pairwise comparison matrix of the criteria and their summation.

	C1	C2	C3	C4	C5	C6	C7	C8
C1	1.00	0.16	0.12	0.16	0.11	0.16	0.33	0.17
C2	5.99	1.00	0.11	0.12	0.12	0.12	0.33	0.11
C3	8.00	9.00	1.00	0.25	0.13	0.25	0.25	0.20
C4	6.00	8.00	4.00	1.00	0.20	0.25	0.25	0.16
C5	9.00	8.00	8.00	5.00	1.00	0.33	0.50	0.50
C6	5.99	8.00	4.00	3.00	2.00	1.00	0.50	0.25
C7	3.00	3.00	4.00	4.00	2.00	1.00	1.00	0.11
C8	5.99	9.00	5.00	3.99	2.00	3.00	8.00	1.00
SUM	44.97	46.16	26.23	17.52	7.56	6.11	11.16	2.50

Table 7 shows the pairwise comparison matrix of cloud mining service providers according to the algorithm used. Table 8 presents a summary of the consistencies for each criterion under the cloud mining strategy.

Based on each alternative's obtained scores, we ranked the service providers under cloud mining, hosted mining, and home mining strategies.

As displayed in Table 9, the cloud mining service provider CM7 ranks first, followed by CM3 and CM6, within the whole set of nine service providers. In other words, CM7 is by far the best choice for investors who tend to implement the cloud mining strategy.

We follow the same methodology to determine the best hosted mining service provider. Table 10 provides the ranking of hosted mining service providers. Of the four hosted mining service providers, HM2 was identified as the best choice, followed by HM4, for investors who are willing to use a hosted mining strategy.

Table 11 presents the ranking of home mining locations in terms of location choice criteria. The results show that Turkey ranks first, followed by Europe and the U.S. This finding is not particularly surprising as Turkey has the lowest rates of electricity, heating, and rent relative to the other two locations.

According to the AHP technique, CM7 was found as the best performing cloud mining service provider, while HM2 was noted to be the best hosted mining service provider. Finally, Turkey was determined to be the best location for the home mining strategy.

After determining the best service providers for cloud and hosted mining strategies and the best location for home mining strategy, we applied the Fuzzy-TOPSIS method along with sensitivity analysis to select and justify the best mining strategy.

At the outset, we asked the same five experts to linguistically rate the selection criteria for cryptocurrency mining strategies, provided in Appendices 1 to 3. Table 12 shows the linguistic ratings of the overall cost and payout criteria for three cryptocurrency mining strategies, while Table 13 indicates the criteria weighting assigned to these two criteria to conduct the Fuzzy-TOPSIS analysis.

Later, we transformed those linguistic variables into fuzzy numbers. Tables 14 and 15 show the combined decision matrix and normalized fuzzy decision matrix, respectively.

The next step is to compute the weighted normalized fuzzy decision matrix by multiplying the criteria' weights with the normalized fuzzy matrix. Table 16 gives the results of the weighted normalized fuzzy decision matrix for the mining strategies.

Then, we calculated the fuzzy positive and negative ideal solutions as in the Fuzzy Positive-Ideal Solution (FPIS) and the Fuzzy Negative-Ideal Solution (FNIS). We computed the distance from each alternative strategy to both the FPIS and the FNIS (see Tables 17 and 18).

Finally, we calculated the closeness coefficient (CC_i) to get the ranking order for the three mining strategies. As Table 19 shows, the ranking is based on the calculated CC_i, where the highest coefficient (0.5978) belongs to the hosted mining strategy, followed by the second highest coefficient (0.4021) belonging to home mining, and at last, the coefficient (0.2945) belongs to the contract mining strategy.

Table 5
Normalized pairwise comparison matrix and the criteria weights.

	C1	C2	C3	C4	C5	C6	C7	C8	C.W.
C1	0.022	0.003	0.005	0.009	0.015	0.026	0.030	0.067	0.022
C2	0.133	0.022	0.004	0.007	0.016	0.020	0.030	0.044	0.133
C3	0.178	0.195	0.038	0.014	0.017	0.041	0.022	0.080	0.178
C4	0.133	0.173	0.152	0.057	0.026	0.041	0.022	0.064	0.133
C5	0.200	0.173	0.305	0.285	0.132	0.054	0.045	0.200	0.200
C6	0.133	0.173	0.152	0.171	0.265	0.164	0.045	0.100	0.133
C7	0.067	0.065	0.152	0.228	0.265	0.164	0.090	0.046	0.067
C8	0.133	0.195	0.191	0.228	0.265	0.491	0.717	0.400	0.133
SUM	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 6
Multiplication of the sum values and the criteria weights.

Sum	C.W.	Sum*CW
44.97	0.02	0.90
46.16	0.02	0.92
26.23	0.04	1.05
17.52	0.07	1.23
7.56	0.14	1.06
6.11	0.16	0.99
11.16	0.15	1.72
2.50	0.39	0.99

The robustness of experts' preferences of ranking cryptocurrency mining strategy selection parameters has been tested by sensitivity analysis. This analysis indicates how changes in decision-makers' preferences would affect the ranking of cryptocurrency mining strategy combinations by each scenario. The results of sensitivity analysis for all three scenarios by the CC_i are shown in Table 19. The first scenario includes the initial results of Fuzzy-TOPSIS. The results in the other two scenarios confirm the validity of the initial rankings denoted in the first scenario. The highest coefficient belongs to the hosted mining strategy, followed by home mining and contract mining strategies, respectively.

5. Discussion, implications, and limitations

Crafting and executing the best cryptocurrency mining strategy determine the success of investment in cryptocurrency markets. This study has contributed to business analytics literature by examining cryptocurrency mining strategies and evaluating cryptocurrency mining service providers' performance through an integrated hybrid analytics technique (i.e., AHP and Fuzzy-TOPSIS).

Our empirical findings indicated that hosted mining was the best cryptocurrency mining strategy, followed by home mining and cloud mining, based on overall cost and cryptocurrency payout criteria. Another significant finding emerging from this study has made it clear that the highest performing service providers' key features for both hosted mining and cloud mining strategies were their contracts' flexibility and their superior efficiency in terms of the daily payout. Besides, the home mining strategy avoids transactional fees and supplies BTC instantly while miners can select the pools directly or earn other

Table 8
Consistency ratios for each criterion under cloud mining strategy.

	C1	C2	C3	C4	C5	C6	C7	C8
	9.31	10	9.8	10.07	10.2	9.13	9.15	10.3
CI	0.02	0.125	0.1	0.13	0.15	0.01	0.01	0.16
RI	1.45	1.45	1.45	1.45	1.45	1.45	1.45	1.45
CR	0.01	0.08	0.06	0.09	0.1	0.01	0.01	0.11

Table 9
Ranking of cloud mining service providers.

Alternatives	Ratings	Ranking
CM1	0.02027	9
CM2	0.05990	8
CM3	0.17381	2
CM4	0.09571	5
CM5	0.10122	4
CM6	0.13517	3
CM7	0.25682	1
CM8	0.08281	6
CM9	0.07430	7

Table 10
Ranking of the hosted mining service providers.

Alternatives	Ratings	Ranking
HM1	0.08404	4
HM2	0.43300	1
HM3	0.13369	3
HM4	0.34927	2

Table 11
Ranking of the alternative locations for home mining strategy.

Locations	Ratings	Ranking
Turkey	0.50683	1
Europe	0.24902	2
U.S.	0.24415	3

Table 7
Pairwise comparison matrix of the cloud mining service providers according to the algorithm used.

	CM1	CM2	CM3	CM4	CM5	CM6	CM7	CM8	CM9
CM1	1.00								
CM2	1.00	1.00							
CM3	1.00	1.00	1.00						
CM4	4.20	4.20	4.20	1.00					
CM5	1.00	1.00	1.00	0.64	1.00				
CM6	1.00	1.00	1.00	0.64	1.00	1.00			
CM7	1.00	1.00	1.00	0.64	1.00	1.00	1.00		
CM8	1.00	1.00	1.00	0.64	1.00	1.00	1.00	1.00	
CM9	1.00	1.00	1.00	0.64	1.00	1.00	1.00	1.00	1.00

Table 12
Decision-makers' linguistic ratings for the cryptocurrency mining alternatives.

	Overall cost	BTC payout
Cloud mining	High	High
Hosted mining	Low	Average
Home mining	Very high	Very high

Table 13
Decision-makers' linguistic ratings for the cryptocurrency mining criteria.

Criteria weighting	
Overall cost	Very high
BTC payout	High

Table 14
Combined decision matrix of the aggregated rating of the cryptocurrency mining strategies.

	Overall cost	BTC payout
Criteria weighting	7, 9, 9	5, 7, 9
Cloud mining	5,7,9	5,7,9
Hosted mining	1, 3, 5	3, 5, 7
Home mining	7, 9, 9	7, 9, 9

Table 15
Normalized fuzzy decision matrix for the cryptocurrency mining strategies.

	Overall cost	BTC payout
Criteria weighting	7, 9, 9	5, 7, 9
Cloud mining	0.2, 0.14, 0.11	0.56, 0.78, 1
Hosted mining	1,0.33,0.2	0.33,0.56,0.78
Home mining	0.14, 0.11, 0.11	0.78, 1, 1

Table 16
Weighted normalized fuzzy decision matrix for the cryptocurrency mining strategies.

	Overall cost	BTC payout
Criteria weighting	7, 9, 9	5, 7, 9
Cloud mining	1.4, 1.26, 0.99	2.8, 5.46, 9
Hosted mining	7,2.97,1.8	1.65,3.92,7.02
Home mining	0.98, 0.99, 0.99	3.9, 7, 9

Table 17
FPIS and FNIS for the cryptocurrency mining strategies.

A^+	7, 2.97, 1.8	3.9, 7, 9
A^-	0.98, 0.99, 0.99	1.65, 3.92, 7.02

Table 18
Distance from each alternative strategy to the FPIS and FNIS.

	Overall cost	BTC payout	D+
Cloud mining	3.412731067	1.092642058	4.505373
Hosted mining	0	2.4812161	2.4812161
Home mining	3.688581480	0	3.688581

	Overall cost	BTC payout	D-
Cloud mining	0.288270706	1.593162473	1.881433
Hosted mining	3.68858148	0	3.68858148
Home mining	0	2.481216100	2.481216

Table 19
Results of sensitivity analysis.

	Scenario 1	Rank	Scenario 2	Rank	Scenario 3	Rank
Cloud mining	0.2945	3	0.29849	3	0.39801	3
Hosted mining	0.5978	1	0.46038	1	0.64068	1
Home mining	0.4021	2	0.39524	2	0.54220	2

cryptocurrencies from the utilization of their hardware. Finally, of the three location alternatives for home mining, Turkey, which represents emerging economies, appears to rank first compared to the U.S. and Europe.

5.1. Managerial implications

This study offers several useful implications for portfolio managers and individual investors. One significant implication emerging from this study reveals that cryptocurrency mining service contracts that tend to offer more flexibility and higher hashing power with relatively low prices are more effective in determining cryptocurrency mining service providers' success. Secondly, the hosted mining strategy offers worthwhile contracts with technical support and flexibility and attracts different types of large-scale investors in cryptocurrency mining service markets. Furthermore, the cloud mining strategy attracts individual investors from budget and performance segments in cryptocurrency mining service markets. While selecting the best cryptocurrency mining strategy offers some obvious advantages (e.g., outsourcing necessary hardware, administrative, technical, and operational support), it still involves some serious market-based and contractual risks due to the lack of auditing, transparency, and monitoring mechanism by a central authority.

Portfolio managers should also carefully consider the potential risks and returns of adding cryptocurrencies for diversification. Crafting a well-performing cryptocurrency mining strategy as an alternative to cryptocurrency trading relies on regular monitoring and assessment of two significant factors: daily payouts and maintenance costs. To exemplify, while the average mining cost of a BTC was estimated to be around USD 6850 before BTC's last halving in May 2020, it has now been almost doubled due to sharp increases in hashing difficulty. Thus, investors who already adopted a particular cryptocurrency mining strategy always expect that the future cryptocurrency prices are more likely to exceed their average mining costs. On the other hand, when the cryptocurrency prices remain below their average mining costs for a long time, some miners may cease to use more hashing power. As long as cryptocurrencies' market prices stay above the average mining cost, cryptocurrency mining continues to be attractive for both investors and portfolio managers. Otherwise, trading would be a more plausible investment decision rather than engaging in cryptocurrency mining.

It should be noted that as compared to cloud mining and home mining strategies, there are some distinct advantages as well as risks of a hosted mining strategy for investors. The latter offers more professional technical features and flexible clauses with lower costs in the contracts. Contract durations also limit investment risks associated with hosted mining and cloud mining strategies compared with home mining. Conversely, professional cloud mining service providers can efficiently manage the continuously increasing hashing difficulties by replacing old miners with new technologies.

Our findings also illustrate that when market conditions are favorable, the hosted mining strategy is the best option due to the following flexibilities of the contract offered by service providers: the length of the contract, new miner capacity, enormous hashing powers, mining alternatives, pool selection options, script choice, professional assistance, professional dashboards, and lower withdrawal limits. However, this strategy requires more technical knowledge of mining when compared to cloud mining.

It should also be noted that the risk of investment in the contracts of cloud mining service providers is very high, as a central authority does not monitor them. Besides, the coverage of maintenance costs in daily operations is not exact due to the absence of a regulatory watchdog, making the efficiency of cloud mining services debatable. Thus, investors have to rely on daily performance reports prepared by marketing experts.

Finally, before selecting a cryptocurrency mining strategy, investors are strongly encouraged to regularly check changes in price levels, global economic conditions, new mining technologies, and the extent of transparency and reliability in cryptocurrency mining services and cybersecurity. Hence, crafting and executing an astute cryptocurrency mining strategy necessitates a better understanding of cryptocurrency market behavior and its ecosystem.

5.2. Limitations and future research

As with all studies, this study has some limitations, which may provide meaningful directions for future research on crypto-economics and business analytics. Since the introduction of BTC in 2008, cryptocurrencies have emerged from opacity to the growing attention of investors, businesses, regulatory authorities, governments, media, and also academicians. Despite this surge in popularity, early studies on cryptocurrencies focused mainly on technical and legal issues. Although recent studies have started to emphasize mostly financial aspects, token economics, on-chain, and off-chain governance, as well as economic incentive systems, more research is called for to understand better the effects of token economics, cryptocurrencies, and blockchain on the economy and how the emerging technology is going to reshape organizations. There is also a potential research gap for cryptocurrency asset management. Researchers may examine cryptocurrencies in portfolio management by elaborating on the effects of diversified portfolios with several leading cryptocurrencies.

As cryptocurrencies are increasingly becoming popular across individuals of all groups of different ages, gender, and trading patterns, future studies can be conducted on the role of demographic differences in the selection process of cryptocurrencies for investment decisions. The selection process of a cryptocurrency for a cloud mining strategy, pool selection, optimization of cryptocurrency mining algorithms are also some possible areas for future research in cryptocurrency mining.

Though still in its beginning stages, business analytics has an immense potential to analyze the cryptocurrency ecosystem dynamics towards creating value for market players. Innovative business analytics tools can also be utilized to identify fake or dangerous users, prevent theft, and predict market trends in the cryptocurrency mining business.

The study is relying on perceptual data provided by the experts, which may not provide clear and universally generalizable measures of subjective and opinion-based inputs. However, as is the case in this study, this limitation can be mitigated by using more than one subject matter expert to collect the data. Furthermore, while we used an integrated MCDM technique, other similar tools in the fuzzy environment such as Fuzzy-AHP, VIKOR, Weapon Target Assignment (WTA), and PROMETHEE could be employed jointly in future studies to evaluate the mining of the best alternative cryptocurrency or select the best performing mining pool.

Appendix A. Appendix

Cryptocurrency mining service features

Cloud mining service providers	Crypto-currency	Algorithm	Minimum hash rate	Price	Maintenance cost	Contract length	Minimum withdrawal
Hashflare (CM1)	LTC	SCRYPT	1 M.H./s	$1.80/1MH/s	$0.005/1MH/s/24 h	1 year	None
	BTC	SHA-256	10 G.H./s	$0.60/10GH/s	$0.0035/10GH/s/24 h	1 year	0.03
	ETH	ETHASH	100 KH/s	$1.40/100KH/s	None	1 year	0.10
	ZCASH	EQUIHASH	1H/s	$1.40/1H/s	None	1 year	0.10
	DASH	X11	1 M.H./s	$3.20/1MH/s	None	1 year	0.10
Genesis Mining (CM2)	BTC Classic	SHA-256	3 TH/s	$125	$0.15/TH/s/day	18 + 3 Months	0.0005
			35 TH/s	$1389	$0,15/TH/s/day		
			140 TH/s	$5292	$0.15/TH/s/day		
	BTC Zero	SHA-256	1.5 TH/s25 T.H./s	$182	None	18 Months	0.0005
			44 T.H./s	$3037	None		
				$5346	None		
	Dash Class	X11	25 GH/s	$80	$0.00001/MH/s/day	12 + 3 Months	0.001
			250 GH/s	$764	$0.00001/MH/s/day		
			2 K GH/s	$5820	$0.00001/MH/s/day		
	Dash Zero	X11	11 G.H./s	$75	None	12 Months	0.001
			110 GH/s	$753	None		
			800 GH/s	$5478	None		
	ETH	ETHASH	25 MH/s	$525	$0.004/MH/s/day	24 Months	0.02
			75 MH/s	$1500	$0.004/MH/s/day		0.002
			350 MH/s	$6650	$0.004/MH/s/day		0.002
	LTC	SCRYPT	2 M.H./s	$28	None	24 Months	0.002
			50 M.H./s	650	None		0.002
			200 MH/s	2400	None		0.002
	Monero	CryptoNight-R	1 KH/s	$830	None	24 Months	0.1
			3 KH/s	$2460	None		0.1
			9 KH/s	$7200	None		0.1
	Zcash	EQUIHASH	200H/s1 K.H./s			24 Months	
			3 K.H./s				

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Cloud mining service providers	Crypto-currency	Algorithm	Minimum hash rate	Price	Maintenance cost	Contract length	Minimum withdrawal
				$530	None		0.001
				$2600	None		0.001
				$7650	None		0.001
Crypto Universe (CM3)	BTC	SHA-256	1 TH/s	$8.90	$0.09/TH/s/day	1 Year	0.005
			1 TH/s	$9.90	$0.1/TH/s/day	2 Years	0.005
			1 TH/s	$10.90	$0.1/TH/s/day	3 Years	0.005
			1 TH/s	$12.90	$0.13/TH/s/day	01.01.2025	0.0005
			400 TH/s	$3800	$0.095/TH/s/day	3 Years	0.0005
			500 TH/s	$5250	$0.125/TH/s/day	01.01.2025	0.0005
	LTC	SCRYPT	300 MH/s	$27/100 MH/s	$0.0027/MH/s/day	01.01.2025	0.01
			900 MH/s	$21/100 MH/s	$0.0026/MH/s/day	360 Days	0.01
			3 K MH/s	$24/100 MH/s	$0.0021/MH/s/day	480 Days	0.01
			5 K MH/s	$22/100 MH/s	$0.0019/MH/s/day	720 Days	0.01
IQ Mining (CM4)	BTC	SHA-256	1.8 TH/s	$38	$0.001/10 GH/s/day	1 Year	0.001
			1 TH/s	$38	$0.001/10 GH/s/day	2 Years	0.001
			500 GH/s	$38	$0.001/10 GH/s/day	5 Years	0.001
			300 GH/s	$38	$0.001/10 GH/s/day	Lifetime	0.001
			2.2 TH/s	$45	$0.001/10 GH/s/day	1 Year	0.001
			1.2 TH/s	$45	$0.001/10 GH/s/day	2 Years	0.001
			641 GH/s	$45	$0.001/10 GH/s/day	5 Years	0.001
			361 GH/s	$45	$0.001/10 GH/s/day	Lifetime	0.001
	ETH	ETHASH	8 M.H./s	$32	None	1 Year	None
			4 M.H./s	$30	None	2 Years	None
			2 M.H./s	$30	None	5 Years	None
			1.4 MH/s	$31	None	Lifetime	None

Cloud mining service providers	Crypto-currency	Algorithm	Minimum hash rate	Price	Maintenance cost	Contract length	Minimum withdrawal
	Zcash	EQUIHASH	1 K.H./s	$33	$0.07/1KH/s/day $0.07/1KH/s/day $0.07/1KH/s/day	1 Year	None
			0.6 KH/s	$32	$0.07/1KH/s/day	2 Years	None
			0.4 KH/s	$34		5 Years	None
			0.3 KH/s	$40		Lifetime	None
Fly Mining (CM5)	BTC	SHA-256	0.2 TH/s	$42	$0.12/TH/s/day	5 Years	Fee: 0.00005
			1 TH/s	$210	$0.12/TH/s/day	5 Years	Any rate!
			1 TH/s	$63	$0.12/TH/s/day	1 Year	
			5 TH/s	$315	$0.12/TH/s/day	1 Year	
			1 TH/s	$12/ Month	$0.12/TH/s/day	Monthly	
			5 TH/s	$60/ Month	$0.12/TH/s/day	Monthly	
	ETH	ETHASH	1 MH/s	$7	$0.011/MH/s/day	1 Year	None
			5 MH/s	$35	$0.011/MH/s/day	1 Year	None
Bitdeer (CM5)	BTC	SHA-256	50 TH/s	$1642.5	$0.0782/TH/day $0.0782/TH/day $0.0851/TH/day	420 Days	0.01
			100 TH/s	$3285	$0.0851/TH/day $0.0851/TH/day $0.0851/TH/day	420 Days	0.01
			50 TH/s	$1531.5		360 Days	0.01
			50 TH/s	$1287		300 Days	0.01
			100 TH/s	$2574		300 Days	0.01
			100 TH/s	$3063		300 Days	0.01
	BCH	SHA-256	50 TH/s	$1642.5	$0.0782/TH/day $0.0782/TH/day $0.0851/TH/day	420 Days	0.01
			100 TH/s	$3285	$0.0851/TH/day $0.0851/TH/day $0.0851/TH/day	420 Days	0.01
			50 TH/s	$1531.5		360 Days	0.01
			50 TH/s	$1287		300 Days	0.01
			100 TH/s	$2574		300 Days	0.01
			100 TH/s	$3063		300 Days	0.01
Nuvoo (CM7)	BTC	SHA-256	0.10 TH/s	$4.7	$0.17/ TH/s/day	12 Months	0.002
			0.50 TH/s	$23.5	$0.17/ TH/s/day	12 Months	0.002
			1 TH/s	$47	$0.17/ TH/s/day	12 Months	0.002
			2 TH/s	$94	$0.17/ TH/s/day	12 Months	0.002
			5 TH/s	$235	$0.17/ TH/s/day	12 Months	0.002
			15 TH/s	$705	$0.17/ TH/s/day	12 Months	0.002
			30 TH/s	$1410	$0.17/ TH/s/day	12 Months	0.002
			75 TH/s	$3525	$0.17/ TH/s/day	12 Months	0.002
			150 TH/s	$7050	$0.17/ TH/s/day	12 Months	0.002
			300 TH/s	$14,100	$0.17/ TH/s/day	12 Months	0.002
			600 TH/s	$28,200	$0.17/ TH/s/day	12 Months	0.002
			0.10 TH/s	$5.4	$0.17/ TH/s/day	24 Months	0.002
			0.50 TH/s	$27	$0.17/ TH/s/day	24 Months	0.002
			1 TH/s	$54	$0.17/ TH/s/day	24 Months	0.002
			2 TH/s	$108	$0.17/ TH/s/day	24 Months	0.002
			5 TH/s	$270	$0.17/ TH/s/day	24 Months	0.002
			15 TH/s	$810	$0.17/ TH/s/day	24 Months	0.002
			30 TH/s	$1620	$0.17/ TH/s/day	24 Months	0.002
			75 TH/s	$4050	$0.17/ TH/s/day	24 Months	0.002
			150 TH/s	$8100	$0.17/ TH/s/day	24 Months	0.002

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Cloud mining service providers	Crypto-currency	Algorithm	Minimum hash rate	Price	Maintenance cost	Contract length	Minimum withdrawal
			300 TH/s	$16,200	$0.17/ TH/s/day	24 Months	0.002
			600 TH/s	$32,400	$0.17/ TH/s/day	24 Months	0.002
CCG Mining (CM8)	BTC	SHA-256	100 GH/s	$10.99	$0.00017/GH/s/day	1 Year	0.002
			400 GH/s				
				$45.99	$0.00017/GH/s/day	1 Year	0.002
			100 GH/s				
				$12.99	$0.00017GH/s/day	Unlimited	0.002
			400 GH/s				
			15 TH/s	$49.99	$0.00017/GH/s/day	Unlimited	0.002
				$1659.99	$0.00017/GH/s/day	Unlimited	0.002
	BCH	SHA-256	100 GH/s	$17.29	$0.00037/ GH/s/day	1 Year	0.063987
			400 GH/s	$49.99	$0.00037/ GH/s/day	1 Year	0.063987
			25 TH/s	$2959.99	$0.00037/ GH/s/day	1 Year	0.063987
			100 GH/s	$24.99	$0.00037/ GH/s/day	Unlimited	0.063987
			400 GH/s	$82.99	$0.00037/ GH/s/day	Unlimited	0.063987
			15 TH/s	$2979.99	$0.00037/ GH/s/day	Unlimited	0.063987
	ETH	ETHASH	1 M.H./s	$13.89	None	1 Year	0.099337
			30 M.H./s	$410	None	1 Year	0.099337
			100 MH/s	$1340	None	1 Year	0.099337

Cloud mining service providers	Crypto-currency	Algorithm	Minimum hash rate	Price	Maintenance cost	Contract length	Minimum withdrawal
	ZEC	EQUIHASH	20H/s	$27.99	None	1 Year	0.489816
			250H/s	$349.99	None	1 Year	0.489816
			2.6 KH/s	$3700.99	None	1 Year	0.489816
			20H/s	$34.99	None	2 Years	0.489816
			250H/s	$425.99	None	2 Years	0.489816
			2.6 KH/s	$4389.99	None	2 Years	0.489816
	MONE-RO	CryptoNight-R	60H/s1 K.H./s	$46.99	None	2 Years	0.297006
			3 K.H./s	$769.99	None	2 Years	0.297006
				$2279.99	None	2 Years	0.297006
	LTC	SCRYPT	2 M.H./s	$25.99	None	2 Years	0.30
			50 M.H./s	$616.99	None	2 Years	0.30
			200 MH/s	$2279.99	None	2 Years	0.30
BTC Pool (CM9)	BTC/ BCH	SHA-256	10 TH/s	$149.9	$1/TH/s/day $0.50/TH/s/day $0.20/ TH/s/day	6 Months	0.0005
			5 TH/s	$124.95		1 Year	0.001
			2 TH/s	$139.98		2 Years	0.001

Appendix B. Hosted mining service providers and their contract options

D-Central (HM1)

	Power (kW)	Price ($/kW)	Features
Option 1	1–14	90	1 months prepayment Install fee: 30$/unit Mini 2 mo. contract
Option 2	15–29	85	2 months prepayment Install fee: 20$/unit Mini 4 mo. contract
Option 3	+30	80	3 months prepayment Install fee: 10$/unit Mini 6 mo. contract

Oregon (HM2)

	Monthly ($)	Half-year Prepaid ($)	Full-year prepaid ($)
Bitmain L3 + (Optimized), Z9Mini Innosilicon A9	39	226.98	439.92
Avalon 9 series, Obelisk SC1 (750 W-900 W)	41	238.62	465.48
Bitmain L3+ (not optimized), E3	46	267.72	518.88
GPU Rig in 4 U Case (max 1000 watts)/Bitmain Z9	51	296.82	575.28
Bitmain S11, S15/Ebit E9/Innosilicon S11/Strong U6-X11	66	384.12	744.48
Bitmain S9, Z11/Avalon 852	72	419.04	812.16
Strong STU-U2	82	477.24	924.96
Bitmain S17, S17 Pro, T17/Innosilicon T2T 30	112	651.84	1263.36
Avalon 10 series	128	744.96	1443.84
Innosilicon T2T 50	164	954.48	1849.92
Spondoolies SPx36/Whatsminer M20S	230	1338.60	2594.40

(*continued*)

Oregon (HM2)			
	Monthly ($)	Half-year Prepaid ($)	Full-year prepaid ($)

Blockbase (HM3)			
	Monthly (EUR)	Half-year Prepaid (EUR)	Full-year prepaid (EUR)
Option 1	58	55	51
Option 2	55	51	47
Option 3	51	47	44

Light Speed (HM4)		
	Monthly Fee ($)	Setup Fee ($)
Obelisk SC1/DCR1 Gen1	66	25
Obelisk SC1-3 Board	88	25
Obelisk SC1imm	185	25
Baikal BK-G28	115	25
Hashaltcoin Blackminer F1	77	25
Dayun Zig D2	240	25
Dayun Zig Z1 Pro	127	25
Obelisk DCR1-3	82	25
Obelisk SC1 Gen2	73	25
Obelisk DCR1 Gen2	66	25
Obelisk GRN1	220	25
Obelisk GRN1 Mini	40	25
Obelisk GRN1 IMMERSION	440	25
Pangolin Whatsminer D1	176	25
Pangolin Whatsminer M20S	330	25
Antminer A3 Miner	82	25
Antminer B3 Miner	58	25
Antminer D3 Miner	91	25
Antminer DR3 Miner	122	25
Antminer DR5 Miner	146	25
Antminer E3 Miner	85	25
Antminer L3+ Miner	100	25
Antminer S9 Miner	120	25
Antminer S9j Miner	118	25

Author statement

All authors have contributed collectively and equally to the original and revised version of this manuscript.

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