International Journal of Finance, Accounting and Economics Studies, 5(3), 2024, 1-18.
Print ISSN: 2251-645X Online ISSN: 2383-2517

Islamic Azad University
Science and Research Branch
Faculty of Management and Economics

International Journal of Finance, Accounting and Economics Studies
Journal Homepage: https://ijfaes.srbiau.ac.ir

Modeling and Simulation of the Bitcoin Price by the System Dynamics Method

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Article History
Submission date: 2024-05-14
Revised date: 2024-11-11
Accepted date: 2024-11-27
Available online: Summer 2024

Abstract:
Regarding to the emerging blockchain technology and the creation of the Bitcoin cryptocurrency based on that, also lots of attention to the economic and financial aspects of Bitcoin in recent years, in this article, the cause-and-effect relationship between bitcoin price and factors has been studied. The price of Bitcoin is modeled by powerful system dynamics tools. Bitcoin like any tradable commodity in the economy is affected by supply and demand, however, variables are defined based on the inherent nature of the bitcoin system. State variable is price and some indices are selected to represent typical supply and demand. Google search is a new variable which reflects market anticipations and acts on the price. The simulation results are consistent with past data by determining the boundaries of the system indicating external factors and internal relationships. The model provides the possibility of predicting future changes based on the assumptions for changes in all causal factors.

Keywords:Bitcoin,Price, Modeling,Simulation,System Dynamics

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1. Introduction:

After the financial crisis in 2008 and the feeling of insecurity towards current fiat currencies and financial intermediaries, it was a good opportunity to introduce Bitcoin digital currency based on blockchain technology (already developed) by Satoshi Nakamoto (Nakamoto, 2008). Bitcoin is a person-to-person decentralized network, where all transactions are recorded in a distributed ledger among the people of the network, also transaction confirmation is decentralized in the form of a unique signature. The parties of the transaction remain anonymous. Fast and safe transaction without fear of twice spending currency is a very important property.

Bitcoin uses the blockchain platform, and data blocks containing transaction information are added to the blockchain during the mining process. The mining process is based on solving mathematical equations by miners, and the motivation of miners is to receive transaction fees and rewards in the form of bitcoins. Bitcoin introduces positive and negative features. Transaction at any time, the absence of intermediaries, the security of transactions due to the block chain and consensus in the approval of transactions (more than 50%) create a type of digital democracy. On the other hand, the lack of sufficient regulations, the anonymity of the parties, and the possibility of being used in criminal and money laundering processes are listed as disadvantages.

2. Literature Review:

Bitcoin was defined as a phenomenon without the usual financial intermediaries and was created on the pretext of the financial crisis in 2008, the existence of defects in the banking system and in a way to circumvent the financial dominance (Hanley, 2013). various expectations and functions were counted once it was published. Bitcoin price analysis divides into two phases. The first phase is like a new experience with extreme fluctuations and the second phase is public attention phase, increasing the number of users and identifying the features of a currency with new characteristics (Kondor et al.,2014). Bitcoin's special advantage is its stability comparing to other cryptocurrencies (Bornholdt and Sneppen, 2014) and it dominates the cryptocurrency market (Neil and Halaburda, 2014). Bitcoin is based on blockchain solution and has a simple, flexible, decentralized network structure with high security (Barber, 2012).

Is Bitcoin a financial transaction tool or an excuse for trading? Bitcoin has a speculative behavior (Bouoiyour and Selmi, 2015), showing both short-term and long-term attractiveness for investment (Bouoiyour et al., 2015). Sometimes it is considered as an alternative to fiat currency without the destructive dominance effect of banks (Hanley, 2013). Some consider it as a valuable fiat currency that is related to the performance of the American economy (van Wijk, 2013). Excess volatility is a sign of speculation, and to become valuable, the daily value needs to be fixed. Considering 21-million-coin numbers in total, it creates a deflationary force (Yermack, 2015).

Some consider it similar to a commodity based on pseudo-money information (Bergstra and Weijland, 2014). Also, it is generally weak for hedging lonely, but in asset diversification (Bouri et al., 2017) and in a portfolio with gold, the dollar index and the stock market to reduce risk is useful (Dyhrberg, 2015). It is considered as an important player in payments without government restrictions and as an alternative for gold (Grinberg, 2012). Despite its popularity as a payment, Bitcoin also serves as an investment asset oppositely (Van Alstyne, 2014). Florian et al showed it is more like an asset because most of the transactions are in the exchanges (Glaser, 2014). The risks associated with Bitcoin include the risk of exchanges which consists of identification of users, collapse of the exchange (Moore and Christin, 2013) and the regulatory mechanism (Grinberg, 2012). Polasic et al showed that Bitcoin has many obstacles such as legal status, confusion of legislators, type of financial goals and illegal activity (Polasik et al., 2015). There is no legal regime to support Bitcoin ownership and it is vulnerable to fraud, theft and hacking (Bouoiyour and Selmi, 2015). Although the approval behavior is by consensus, it can change based on the condition's variation and the pressure of the legislator can limit the power of the participants to some extent (Kroll et al., 2013).

Dahham & Ibrahim investigated the determinants of cryptocurrencies price. The price difference among cryptocurrencies is due to their reputation and history. Government regulations are effective in general. The founder team, stock market index, crypto exchange rate and google search have a positive effect. Public demand is influential (Dahham and Abdu Ibrahim, 2020).

Siddharth et al argued that two factors of computing power (hash rate) and network (number of users) affect the price of cryptocurrencies in the long term. The number of unique addresses represents the number of users and liquidity as well. A large network is a sign of cryptocurrency acceptance. Cryptocurrencies have intrinsic value associated with blockchain computing power and network acceptance. There is a statistically significant relationship between aggregated computing power and network size (Bhambhwani et al., 2019).

Where does the value of a cryptocurrency come from? Hayes believes that cost of production determines the value which is well noted in the competitiveness of cryptocurrencies. The computing power, type of mining algorithm and producing number of coins per minute is directly related to the value. In other words, crypto value depends on the policy of each currency, the growth rate and the total number of coins in circulation competitively (Hayes, 2017).

Many studies have been done on determining and predicting the price. Bitcoin pricing has been investigated from different views. Google search, the number of posts on social networks and the number of views on Wikipedia represent indicators of feeling, reputation or attention of investors are as the most important new aspect of pricing in the digital world. A strong two-way causal relationship has been identified too (Kristoufek, 2017; das Neves, 2020; Cretarola and Talamanca, 2018; Kapar and Olmo 2020; Kjærland, 2018; Goczek and Skliarov, 2019; Bouoiyour and Refk Selmi, 2017). Sussmuth showed that there is a two-way causal relationship with price predictability in the frequency of 2 to 5 months by combining Google and Baidu search results (Süssmuth, 2018). Goczek & Skliarov stated that the main factor driving price is reputation (Goczek and Skliarov, 2019).

For the first time, Ciaian et al. specifically separated the three categories of supply and demand pressure, investment attractiveness (online search) and macro-financial-economic variables in order to model pricing and examined the mutual effect of the categories and price simultaneously. Bitcoin price is divided into two periods of introduction and stabilization. The main determining factor, especially in the late period, is the pressure of supply and demand. Speculative behavior makes short-term, supply and demand specify long-term pricing. finally, macro-financial and economic indicators such as the price of oil and the Dow Jones index do not stimulate the price of Bitcoin (Ciaian et al, 2016).

Zhu et al examined several economic variables affecting the price of Bitcoin. They stated that supply and demand have no serious effect. They found that inflation, Dow Jones index, federal interest rate, dollar price, dollar index in the long term and inflation variables, gold price, dollar index in the short-term impress Bitcoin price (Zhu et al, 2017).

Bouoiyour identified 9 modes using signal processing method. Three modes act in high frequency or short-term operation (less than 56 days), two modes operate in medium frequency between 56 and 315 days and four modes operate in high frequency or long-term (over one year). He confirmed the long-term basis determines the price speculative behavior (Bouoiyour et al., 2016).

Kristoufek argued that fame or attention (Google Engine and Wikipedia) drives Bitcoin's price through increasing demand. By defining the ratio of the volume of currency in the exchange to the volume of currency for goods trades as an index in order to determine short- and long-term demand, it was found that trades as long-term signal causes increase in the volume of exchanges and is capable for bubbles in the short term consequently. Following, the price itself causes price volatility in short term. In long term, the use of Bitcoin increases the demand and price. The difficulty increase leads to the exit of miners, converting them to buyers, increasing the demand and affecting the price then, and the price of Bitcoin leads the difficulty in the long term relatively. There is no relation to the Chinese market and is not connected to the dynamics of gold and is not a safe haven investment too (Kristoufek, 2015). Kapar and Olmo state that the only effective variable in the long term is online search and not market fundamentals (Kapar and Olmo, 2020).

Several factors have been considered to examine their influence on the price such as the S&P index factor with positive effect (Kapar and Olmo, 2020), S&P with lack of correlation (Light, 2019), also with positive and large effect (Kjærland et al., 2018 and Havidz et al., 2021). On the other hand, negative effect of the stock market index of 18 selected emerging countries has been observed (Goczek and Skliarov, 2019). Regarding the price of gold, negative effect (Kapar and Olmo, 2020), negative effect in bear regime (Bouoiyour and Selmi, 2017), lack of connection (Kjærland et al., 2018 and Deniz and Teker, 2019) and positive relation (Havidz et al., 2021) have been concluded. The federal interest rate has no effect (Light, 2019). An increase in interest rates has been investigated to reduce the price (Havidz et al., 2021). Hash rate as technological factor has been known unrelated (Kjærland et al., 2018). Fear in the financial markets has no effect (Kjærland et al., 2018), the shock of the global economic conditions is meaningless (Goczek and Skliarov, 2019). Oil price has no effect (Kjærland et al., 2018 and Deniz and Teker, 2019). The supply and demand factor, including the volume of exchange transactions, has no effect on trades (Light, 2019 and Goczek and Skliarov, 2019). Commodity price does not have a stable effect (Goczek and

Skliarov, 2019). The exchange rate of 18 countries has a positive effect on Bitcoin price (Havidz et al., 2021).

Light believes that supply and demand variables representing macro-financial factors are not effective, and only system-specific variables including unique addresses (Bitcoin's increasing adoption index) and hash rate are related (Light, 201).

Goczek and Skliarov state the perception of future scarcity along with reputation raise the price (Goczek and Skliarov, 2019). Merkas and Roska were able to show the bitcoin price trend based on the scarcity defined by a non-systematic rate variable including the number of bitcoins available to the number of remaining bitcoins. The chart includes the trend and does not include fluctuations (Merkaš and Roška, 2021).

Bouoiyour also included political factors in the calculations. Confidence decline in yuan currency has negative effect, uncertainty around Brexit, India's demonetization policy in the bull regime has positive effect, limited supply has negative effect, the ratio of exchange volume to the volume of trades has positive effect and gold, Venezuela's monetary policy and hash rate has a negative effect on bear regime. Google search is always related to price (Bouoiyour and Selmi, 2017).

Buchholz et al investigated the effect of price volatility and found that volatility before the peak has positive effect on price, but after the bubble burst, there is no statistically significant relationship. The influence is defined so that the fluctuation increases the price, which in turn, causes an increase in demand, then an increase in price and vice versa (Buchholz et al., 2012).

Technological specifications and price have also been reviewed. Kristoufek has investigated the causal relationship between Bitcoin price and mining cost. The profitability of mining converged to zero like a standard business in the long run, and the price of Bitcoin drives mining (Kristoufek, 2019). Marthinson & Gordon show that price growth increases difficulty and the cost of entry and exit of business members consequently, contrary to the fact that cost drives price. The mathematical algorithm determines the production of Bitcoin. Improving the technology increases the hash power and has no effect on the production rate. Any additional profit from mining as a result of any shock tends to zero in the long run (Marthinsen and Gordon, 2022).

The system dynamics method has been used for modeling. System dynamics has been introduced as a new method of modeling of various social systems. This method simulates systems by creating a dynamic hypothesis, discovering cause and effect relationships between state variables and dependent variables then converting them into mathematical formulas. The model consists of a series of established patterns and circular causal diagrams. The elements of the model also include accumulation variables (integral) and flow variables (derivative) inside causal loops (Sterman, 2000 and Mashayekhi, 2023).

Lassi & Saul showed that Bitcoin mining including hardware and miners can be modeled as a dynamic system. According to the efficient market hypothesis, any transformation of the Bitcoin network will make the zero profit by negative feedback loop with time delay at the end (Lasi and Saul, 2020).

Majakivi proposed a model and relationships between different variables without any simulation. Users, including enthusiasts (early adopters), speculators, criminals and long-term investors and businesses, create demand. A group of relations and regulations act on the price positively or negatively. Scarcity and financial governance are important reasons to invest. Ambiguous future, different motivations and the role of enthusiasts to migrate to other technologies act as effective factors. The source of Bitcoin price growth is now mostly speculation. People's attention is the first important reason. Liquidity rate is positive too (Majakivi, 2019).

Gopalakrishnan modeled and simulated the Bitcoin ecosystem and pricing. The modeling of the supply side is the mechanism of mining, adding blocks and rewarding Bitcoin. The modeling of the demand or the market side is the decision-making mechanism of different users, including chartists, fundamental analysts, trader of goods and services, dealers plus miners. That also modeled the motivation of participants along with the additional risk involved in legal transactions and the need for regulation in tough situations to protect public sector.

Dividing the life period into three stages, the first 8 years with zero value, the second period including an exponential jump in 2017 and an excessive fall after as start of realization of the long-term value in the market, the third period of relatively increase and a smaller fall in 2020, facilitate modeling. it became more widely known after 2020. Afterwards institutional investors and funds started to operate.

Basic indicators of the system

1. Mining difficulty balance for every 10 minutes a block, Bitcoin production

2. Cost benefit of mining, decision to be a miner

3. Larger network liquidity based on more bitcoins

4. Fundamental and speculative investment

5. The impact of the halving event can be defined (Gopalakrishnan, 2022)

3. Methodology and Modeling

The proposed model is generally built on supply and demand concept. Considering the stability of the production rate on the supply side, the scarcity factor determines the price on the supply side. Demand is divided into two parts: normal demand and long-term demand. The new factor, apart from supply and demand, is the Google search factor, which is another representative of the demand side and is defined in the virtual world.

The supply sector is almost constant due to the fixed rate of block production and the clarity of the bitcoin reward of each block. This sector is effective on the price through the scarcity variable (Kjærland et al., 2018). The effect of halving, which is the nature of Bitcoin technology in the supply side, causes changes in the price in the form of shock function.

The demand section has parameters that are used from the research literature. The price variable directly creates the search in the price-search causal loop. The price rate is determined by knowing the search quantity consequently. In demand loop, by defining the variable of volume of exchange transactions to the number of actual trades, the demand variable is made. This variable creates short-term demand called TVC Demand through a positive feedback loop. Another demand loop, which is concerned long-term demand, is represented by the bitcoin adoption variable. Bitcoin acceptance variable includes the impact of Bitcoin lifetime variable (longer life means more acceptance), independent addresses representing the level of acceptance of Bitcoin by the society and the transaction state variable which is made according to the change in the price rate and shows the fluctuation of acceptance resulting from transaction volume. Both of the daily demand part called the TVC Demand variable and the long-term demand representing the acceptability of Bitcoin constructing total demand will have an effect on the price rate variable. In fact, bitcoin price is a state variable that is increased or decreased with the rate variable called price rate. Factors affecting the price of Bitcoin through this variable change the price ultimately.

Finally, according to the determination of the system boundaries in the model, an exogenous variable is defined as the effect of evolutions, which are the halving effect, the interest rate effect mentioned in the supply section, and the news effect. The causal closed loop diagram of the model is as figure 1.

As shown in the model, the price of Bitcoin depends on the parameters of Bitcoin production (scarcity factor), Google search, real trades, Bitcoin transactions in the exchange, lifespan, the number of independent addresses. Bitcoin trading volume and exogenous variables act on the system by halving every four years, US Federal Reserve interest rate and various news.

Based on the closed loop causal model, the actual model for simulation in Vensim software is shown in figure 2.

3.1. Production or supply of bitcoins

As mentioned, a block of Bitcoin is produced every 10 minutes. Each block addresses a number of bitcoins, which is referred to the reward. Currently, each confirmation of block transactions addresses 3.125 bitcoins. Bitcoin technology started to award 50 Bitcoins in a block during an average of each 10 minutes, and every 4 years the number of Bitcoins is halved. Of course, the time interval of 10 minutes is set every two weeks. Considering the number of miners in competition and the capabilities of the mining devices, the algorithm for generating bitcoin intelligently tries to maintain an average of ten minutes by changing the difficulty of the network. It should be noted that no drastic changes have been contributed in the model. However, at the beginning of the release of Bitcoin, due to the novelty of the technology, the time between the production of two blocks increased to even 29 minutes and sometimes decreased to 7 minutes, but it was entered as a constant average in several specific time periods in the model. The time periods are chosen according to similarity in terms of volatility.

On the other hand, according to the table no. 1, the amount of award is determined during each 4-year time period according to the history of Bitcoin production.

According to the following formula, the number of blocks per day is obtained

Block Number=1440/block interval

Reward*block number=the number of daily Bitcoin supply

Finally, the number of bitcoin supply is drawn daily according to the reward granted for each block in specific period, and the state variable of the number of bitcoins is calculated cumulatively during the simulation period as shown in figure 3.

3.2. Demand side

3.2.1. Google search price section

According to the basic changes resulting to increase of the depth of the Bitcoin market from the beginning till now, the relationship between the variables would also be different during certain and smaller periods of time. The two-way relationship between search and bitcoin price has also shown different behaviors over time. An overview of the change process shows that it is necessary to divide the time period into 8 periods including from the beginning to February 2017, November 2018, June 2021, January 2022, March 2023, October 2023, April 2024 and after. Look up function is used for simulation in vensim software. During simulation, any number given to the function is calculated according to its output graph.

Google search data is ranked from 1 to 100 and is available on a monthly basis, therefore the Look up functions are defined on monthly basis, which does not conflict with the daily input of price. The output of the function is converted into the search number from percentage by a coefficient and entered into the price rate loop. According to the change in behavior, the conversion of search to price is also divided into 9 homogeneous time periods. Dedicated average is multiplied to abovementioned look up function output, forms the price instantaneously. This transformation is expressed with search effect variable shown in figure 4.

3.2.2. Halving effect:

Normally, based on supply and demand theory, the halving of the reward will reduce the supply and increase the price, which almost the historical record of the Bitcoin price approves the fact. The coincidence of the halving event with news effect or inherent developments in the Bitcoin market makes it different in each period. Changes caused by the halving event in the coming years will also be different due to the entry of large financial institutions and the deepening of the Bitcoin market.

As mentioned earlier, the Bitcoin reward has been halved four times, the last time was on April 19, 2024. To enter the halving effect, price changes from one month before to one month after the halving date have been examined and applied as a pulse function on the price rate in the software. During simulation, the halving effect has been checked and entered separately around the time of occurrence in each period. Usually, the price increase caused by the halving is visible a month before it happening. During the four times of the halving process can be used to predict the fifth halving. The increase of attention and traders number, the entry of large institutions and the provision of tools and derivatives, as a result of the growing of the market depth, the effects of the halving will be less and may occur sooner.

3.2.3. Interest rate effect

One of the most important influencing factors in the past two to three years has been the determination of the interest rate by the US Federal Reserve. The interest rate, in other words the dollar price, has become an effective factor on the price of Bitcoin after the easing policy of the Covid-19 period, which caused a sharp increase in the price of Bitcoin. The market is very sensitive to the interest rate announcement by the Federal Reserve. Of course, the dollar price factor is also related to the price of Bitcoin. But the interest rate factor has been chosen as an influential factor due to the correlation between the interest rate and the dollar price. This factor is included in the model with Fed Rate variable. Lately, price reductions can be interpreted when expectations of the interest rate increase, the price cut generally happened before the announcement of the interest rate by the Federal Reserve.

3.2.4. The effect of news and events

Price fluctuations of Bitcoin confirms that is very sensitive to news. Considering the technology is emerging and opens its position in the world, any news causes a change in the price and the share of news cannot be ignored. While examining the evolution of Bitcoin during the period, 102 important news that causes the price to fluctuate is listed. The amount of change in the price which is calculated by past data, is entered into the system as an external variable and affects the price. In each case, the price trend before and after of occurrence has been checked and the changes to reach to the price equilibrium have been calculated. Therefore, the average price is calculated for each fluctuation period and it varies from 3 days to 31 days based on the number of days that the price reaches to relative balance. The number of 102 effective events has been counted, which acts as an impact function as shown in figure 5.

3.2.5. Trade / transaction variable calculations

Past data has been used to create the trade/ transaction variable which represents the real demand in the market. In fact, according to the price, daily transactions and trades and periodic review of these numbers, the relationship between these numbers is designed in the simulation (Ciaian et al., 2016).

The relationship between the price and the number of real transactions has been examined in order to simulate the transactions and five time periods have been determined in terms of the minimum changes during the period. Periods up to 9/1/2018, to 2/5/2018, to 9/6/2019, to 19/3/2020 and the then after are separated, which are created by the communication lookup function based on past data.

On the other hand, exchange transactions are divided into time periods until 12/31/2014, till 11/10/2018 till 5/23/2020 till 8/28/2021 and the period after based on minimum changes in each period. To simplify, the linear relationship between price and volume has been established in each period, the price coefficient will be different according to the average of each period.

The important point in the return loop from the price to the real trades is the one-year delay in the effect of the trades on the price, which is the result of observing the graph of the changes of these two variables. Also, the delay is effective for one day for the volume of exchange transactions which is also true according to the definition. Then the variable of trade to transaction is made by dividing two variables. The effect of this variable is entered into the demand variable through the formula (variable of trade volume/transaction/bitcoin price).

3.2.6. definition of Bitcoin acceptability

The acceptability variable is the product of three variables including age, the number of independent addresses and the volume of aggregated transactions since the beginning of the simulation date. An increase in any variable means an increase in acceptability resulting increase in demand, increase in the price rate and the price of Bitcoin respectively. The acceptability variable is representative of long-term demand.

The independent addresses variable of lookup function f(u) and number of users is made based on past data. The relationship is linear and is formulated from dividing the number of users to a constant calculated as average. Then it is adjusted by dividing by the number of actual trades. The input of the calculations of this variable is the long-term demand, which is the result of this loop. The lifetime variable is proportional to the life time of Bitcoin production from the beginning to 2040, which is the year of mining the last Bitcoin.

On the other hand, to simplify, the volume variable rate is created according to the price rate proportionally, and the state variable is created by aggregating the volume changes. This variable affects the acceptability variable in a linear way and by dividing by the number 9*10*4. Finally, the acceptability variable is generally obtained as a number less than one.

The product of the acceptability variable along with the transaction volume variable in four time periods: 29/1/2020, 24/9/20121, 22/10/2024 and after that with a coefficient related to each period, made the effect of demand on the price rate shown in figure 6.

Finally, the combination of short-term and long-term demand variable will have an impact on the price.

4. Calibration, Validity and Simulation

After formulation, the model was simulated in different conditions. Different time intervals were tested in the communication functions created in the model with different coefficients in the formulation of relationships. The most important aspect of modeling is different functions in different time periods. These functions are built from past data and are divided into separate time periods according to the change in the behavior of the Bitcoin price system. This concept was utilized in Google search and price conversion to exchange transactions.

The time delay of the effect of the causes was also investigated and finally the table 2 was concluded to stabilize values of the model.

The simulation started from 1/7/2010 in daily steps, when the data set was available, and was run until 1/5/2024, step number 5084. After correcting the coefficients of price rate formula for validity, the curve in figure 7 is obtained as the output of the price simulation which is compared to the real price data.

5. Conclusion:

As mentioned, modeling based on supply and demand theory has been done considering the fact that the integrated supply increases almost at a constant rate. An attempt has been employed to model the demand side with the information of the registered indices of Bitcoin in the market. The Google search factor as a new factor has a two-way causality relationship with the price, which is modeled according to the data.

Considering the determination of system boundaries and the determination of internal and external forces, regardless of the 8-year primary period, the model works well, and the most important feature is the externality of positive and negative news force for instance, which is not under the control of the ecosystem. For example, issues related to legislation are determined based on the social actions of players outside the system entering the system as an external factor. Of course, with a careful examination, it can be seen that the effect of various news on the fluctuation of Bitcoin price is reduced and economic variables such as interest rate or economic prosperity, supply and demand will have a greater effect.

While the Bitcoin market deepens and fluctuations decrease, the variables become more predictable and it is possible to expand the boundaries of the Bitcoin system to include new external variables. Also, some indices are measured in the market, which can be used to create better indicators for system variables, including demand. It seems that, whales will be a more decisive factor for bitcoin in the near future due to the accumulation of bitcoins in certain wallets.

6. References

Adam S. Hayes, "Cryptocurrency Value Formation: An empirical study leading to a cost of production model for valuing Bitcoin", Telematics and Informatics, Volume 34, Issue 7, November 2017, Pages 1308-1321, https://doi.org/10.1016/j.tele.2016.05.005

Ahmed Zahim Dahham Dahham, Abdullahi Abdu Ibrahim, "Effects Of Volatility And Trend Indicator For Improving Price Prediction Of Cryptocurrency", IOP Conference Series: Materials Science and Engineering, Volume 928, Issue 3, pp. 032043 (2020), November 2020, DOI:10.1088/1757-899X/928/3/032043

Alessandra Cretarola, Gianna Figà-Talamanca," Modeling Bitcoin Price and Bubbles", Blockchain and Cryptocurrencies journal, 05 November 2018, DOI: 10.5772/intechopen.79386

Alinaghi Mashayekhi, "System Dynamics", book in Persian, 2023

Anne Haubo Dyhrberg, "Hedging Capabilities of Bitcoin Is it the virtual gold?", UCD Centre For Economic Research Working Paper Series, October 2015, http://hdl.handle.net/10419/129339

Antti Majakivi, "Modeling the Bitcoin Ecosystem", Aalto University, School of Electrical Engineering, Master of Science in Technology Thesis, Espoo 31.5.2019

Aric Light, "Bitcoin Price Formation: An Empirical Investigation", Thesis, For the Degree of Master of Arts, Colorado State University, Summer 2019

Bernd Süssmuth, "The mutual predictability of Bitcoin and web search Dynamics", April 2018, Journal of Business Cycle Research 14(1), DOI:10.1007/s41549-018-0026-0

Brian P. Hanley, "The False Premises and Promises of Bitcoin", Computational Engineering, Finance, and Science Submitted on 7 Dec 2013 (v1), last revised 4 Jul 2018 (this version, v8), arXiv:1312.2048, https://doi.org/10.48550/arXiv.1312.2048

Burcu Kapar, Jose Olmo, "Analysis of Bitcoin prices using market and sentiment variables", The World Economy, 2020, 34 Pages, https://doi.org/10.1111/twec.13020

Da´niel Kondor, Ma´rton Po´sfai, Istva´n Csabai, Ga´bor Vattay, "Do the Rich Get Richer? An Empirical Analysis of the Bitcoin Transaction Network", PLOS ONE Published February 5, 2014, Volume 9, Issue 2, https://doi.org/10.1371/journal.pone.0097205

David Yermack, "Is Bitcoin a Real Currency? An Economic Appraisal", Academic Press Handbook of Digital Currency, 2015, Pages 31-43, https://doi.org/10.1016/B978-0-12-802117-0.00002-3

Davide Lasi, Lukas Saul "A System Dynamics Model of Bitcoin: Mining as an Efficient Market and the Possibility of `Peak Hash'" June 2020, Applied Economics and Finance, Vol 7, No 4, 78, DOI:10.11114/aef.v7i4.4872

Dennis van Wijk, "What can be expected from the Bitcoin", Erasmus University, School of Economics, Bachelore Thesis, 2013, September 30, http://hdl.handle.net/2105/14100

E. Asena Deniz, Dilek Teker, "Determinants of Bitcoin Prices", Istanbul Finance Congress ISSN 2459-0762, 2019 Volume 10, p.17-21, DOI: 10.17261/Pressacademia.2019.1136

Elie Bouri, Peter Molnár, Georges Azzi, David Roubaud, Lars Ivar Hagfors, " On the hedge and safe haven properties of Bitcoin: Is it really more than a diversifier?", Finance Research Letters, Volume 20, February 2017, Pages 192-198, https://doi.org/10.1016/j.frl.2016.09.025

Florian Glaser, Kai Zimmermann, Martin Haferkorn, Moritz Christian Weber, Michael Siering, "Bitcoin - Asset or currency? Revealing users' hidden intentions", January 2014, ECIS 2014

Frode Kjærland, Aras Khazal, Erlend A. Krogstad, Frans B. G. Nordstrøm, Are Oust, "An Analysis of Bitcoin's Price Dynamics", Journal of Risk and Financial Management, 11, 63., 2018, https://doi.org/10.3390/jrfm11040063

Hazrati Havidz, Shinta Amalina; Ervina Karman, Viendya; Yudha Mambea, Indra, "Is Bitcoin Price Driven by Macro-financial Factors and Liquidity? A Global ConsumerSurvey Empirical Study", Organizations and Markets in Emerging Economies, vol. 12, núm. 2, pp. 399-414, 2021

Jan A. Bergstra & Peter Weijland." Bitcoin: A Money-like Informational Commodity, arXiv:1402.4778, Submitted on 19 Feb 2014, https://doi.org/10.48550/arXiv.1402.4778

Jamal Bouoiyour, Refk Selmi, "What Does Bitcoin Look Like?", Annals of Economics and Finance, 2015, vol. 16, issue 2, 449-492

Jamal Bouoiyour, Refk Selmi, "The Bitcoin price formation: Beyond the fundamental sources", June 2017, arXiv: Computational Finance, DOI:10.13140/RG.2.2.23880.32000

Jamal Bouoiyour, Refk Selmi, Aviral Kumar Tiwari, "Is Bitcoin Business Income or Speculative Foolery? New Ideas Through an Improved Frequency Domain Analysis", March 2015, Annals of Financial Economics 10(1):1-23, DOI:10.1142/S2010495215500025

Jamal Bouoiyour, Refk Selmi, Aviral Tiwari, Olaolu Olayeni," What drives Bitcoin price?", Economics Bulletin, 2016, vol. 36, issue 2, 843-850

John E. Marthinsen and Steven R. Gordon, "The Price and Cost of Bitcoin", The Quarterly Review of Economics and Finance, Volume 85, August 2022, Pages 280-288, https://doi.org/10.1016/j.qref.2022.04.003

John Sterman, "Business Dynamics: System Thinking and Modeling for Complex World," Mc Graw Hill: New York., 2000, ISBN: 0-07-231135-5

Joshua A. Kroll, Ian C. Davey, and Edward W. Felten, "The Economics of Bitcoin Mining, or Bitcoin in the Presence of Adversaries", The Twelfth Workshop on the Economics of Information Security (WEIS 2013), Washington DC, June 11-12, 2013

Ladislav Kristoufek, "Bitcoin meets Google Trends and Wikipedia: Quantifying the relationship between phenomena of the Internet era", December 2013, Scientific Reports 3(1):3415, DOI:10.1038/srep03415

Ladislav Kristoufek, "What Are the Main Drivers of the Bitcoin Price? Evidence from Wavelet Coherence Analysis", Plos One, April 15, 2015, https://doi.org/10.1371/journal.pone.0123923

Ladislav Kristoufek, "Bitcoin and its mining on the equilibrium path", Energy Economics, Volume 85, January 2020, 104588, https://doi.org/10.1016/j.eneco.2019.104588

Lukasz Goczek & Ivan Skliarov, "What drives the Bitcoin price? A factor augmented error correction mechanism investigation", Applied Economics, Taylor & Francis Journals, vol. 51(59), pages 6393-6410, 22 May 2019, DOI:10.1080/00036846.2019.1619021

Marshall Van Alstyne, “Why Bitcoin Has Value”, Communications of the ACM, Volume 57, Issue 5 ,01 May 2014, DOI: 10.1145/2594288

Martis Buchholz, Jess Delaney, Joseph Warren, Jeff Parker. “Bits and Bets Information, Price Volatility, and Demand for Bitcoin”, Economics 312 Spring 2012

Michal Polasik, Anna Piotrowska, Tomasz Piotr Wisniewski, Radoslaw Kotkowski, Geoffrey Lightfoot, “Price Fluctuations and the Use of Bitcoin: An Empirical Inquiry”, September 2015, International Journal of Electronic Commerce 20(1):9-49, DOI:10.1080/10864415.2016.1061413

Neil Gandal, Hanna Halaburda, “Competition in the Cryptocurrency Market”, in Games 7 (3), 16 NET Institute Working Paper No. 14-17, 9 Oct 2014, Last revised: 29 Dec 2020, http://dx.doi.org/10.2139/ssrn.2506463

Pavel Ciaian, Miroslava Rajcaniova & d’Artis Kancs, “The economics of BitCoin price formation”, Applied Econimics Volume 48, 2016 Issue 19, https://doi.org/10.1080/00036846.2015.1109038

Reuben Grinberg,” Bitcoin: An Innovative Alternative Digital Currency”. Hastings Science Technology Law Journal, Vol. 4 (2012), No. 1

Rodrigo Hakim das Neves, “Bitcoin pricing: impact of attractiveness Variables”, December 2020, Financial Innovation 6(1), DOI:10.1186/s40854-020-00176-3

S. Bornholdt and K. Sneppen, “Do Bitcoins make the world go round? On the dynamics of competing crypto-currencies”, Submitted on 24 Mar 2014, arXiv:1403.6378, https://doi.org/10.48550/arXiv.1403.6378

Satoshi Nakamoto, “Bitcoin: A Peer-to-Peer Electronic Cash System”, Bitcoin White Paper, www.bitcoin.org

Siddharth M. Bhambhwani, Stefanos Delikouras. George M. Korniotisz, “Do Fundamentals Drive Cryptocurrency Prices”, January 2019. SSRN Electronic Journal, DOI:10.2139/ssrn.3342842

Simon Barber, Xavier Boyen, Elaine Shi, Ersin Uzun, “Bitter to Better—How to Make Bitcoin a Better Currency”, International Conference on Financial Cryptography and Data Security February 2012, DOI:10.1007/978-3-642-32946-3_29

Tyler Moore and Nicolas Christin. “Beware the Middleman: Empirical Analysis of Bitcoin-Exchange Risk”, Cryptography, volume 7859 of Lecture Notes in Computer Science, pages 25-33. Springer, 2013.

Vignesh Gopalakrishnan, “Modeling the Trajectory of Bitcoin using System Dynamics”, Submitted to the System Design and Management Program in partial fulfillment of the requirements for the degree of Master of Science in Engineering and Management at the Massachusetts Institute of Technology May 2022

Yechen Zhu, David Dickinson, Jianjun Li, “Analysis on the influence factors of Bitcoin’s price based on VEC model”, December 2017, Financial Innovation 3(1), DOI:10.1186/s40854-017-0054-0

Yiteng Zhang, Guangyan Song, “Economics of Competing Crypto Currencies: Monetary Policy, Miner Reward and Historical Evolution”, MSc Financial Computing at University College London, 2013/2014

Zvonko Merkaš and Vlasta Roška, “The Impact of Unsystematic Factors on Bitcoin Value”, November 2021”, Journal of Risk and Financial Management, 14(11):546, DOI:10.3390/jrfm14110546

Table 1

Date	Award (Number of Bitcoin)
Jan 2009	50
28 Nov 2012	25
8 Jul 2016	12.5
11 May 2020	6.25
19 Apr 2024	3.125
Probably 17 Apr 2028	1.5625

Number of bitcoins awarded each four years

Table 2

Variable	Description
Price Search	Past data Look up function
Price Rate	Price Search * Demand Effect * .023 + Fed Rate + Halving Effect + Event Effect
Transaction Effect	One year delay
Volume Effect	One day delay
TVC Demand	Bitcoin Price / Volume Transaction Criteria
Block Number	1440 / Block Interval
Supply Rate	Block Number * Reward
Scarcity	(e^14.6 * (Supply / 2.1*10^7)^3.3 / Supply
Volume Effect	Total Volume / 4*10^9
Users	(Long Term Demand) * 10^6
Unique Addressees	Users / 436.04
UA Effect	Unique Addresses / Transaction
Bitcoin Adoption	Age * Volume Effect on Demand * UA Effect
Demand Effect	TVC Demand * Demand Rate Above term is multiplied to 1.7, 10 or 0.22 according to defined various time periods

Formulas and Values Concluded for Validation

Figure 1

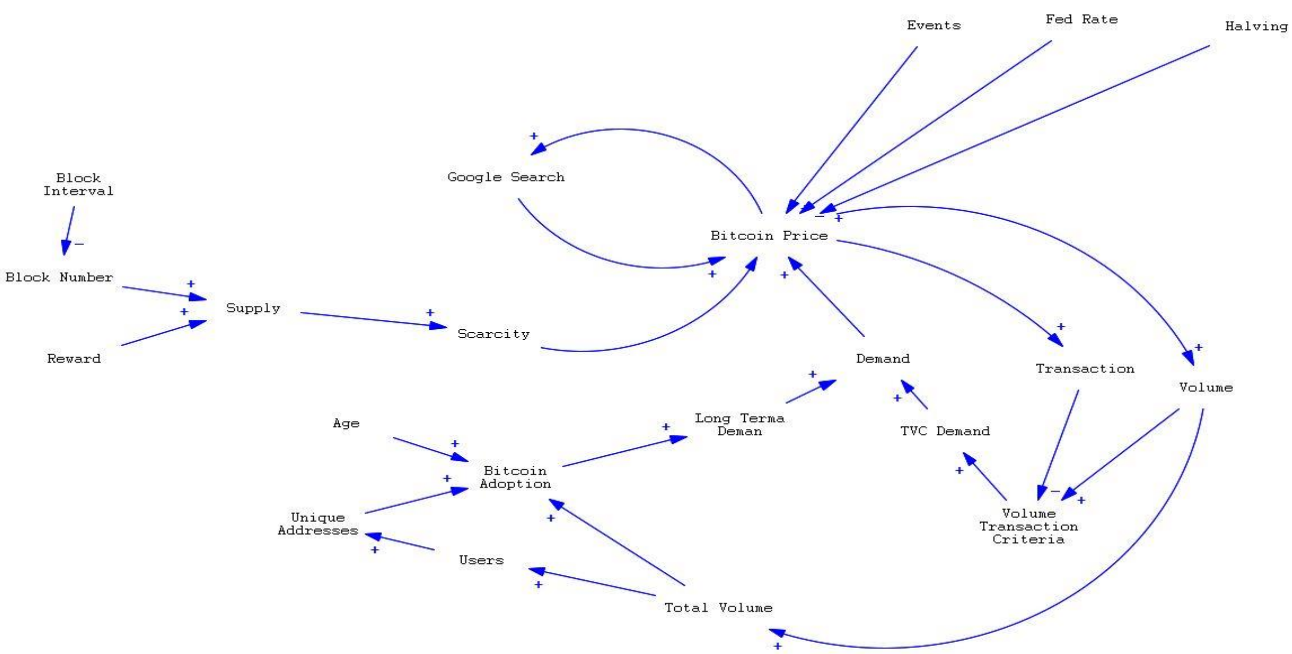


Figure 1: CLD causality model for Bitcoin price

Figure 2

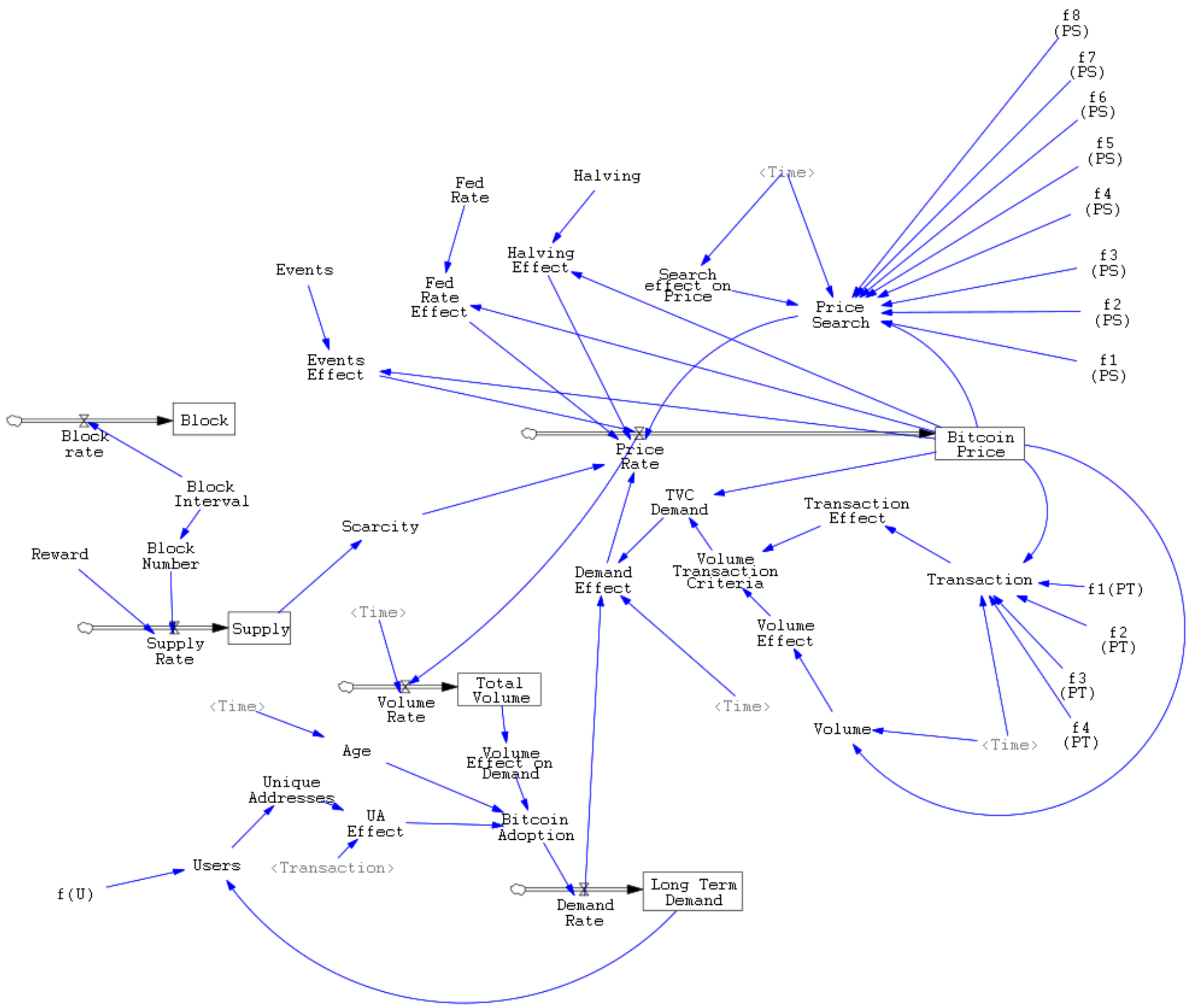
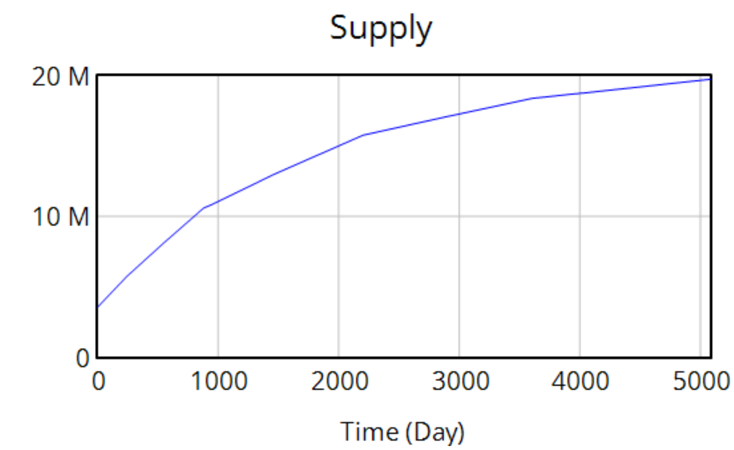


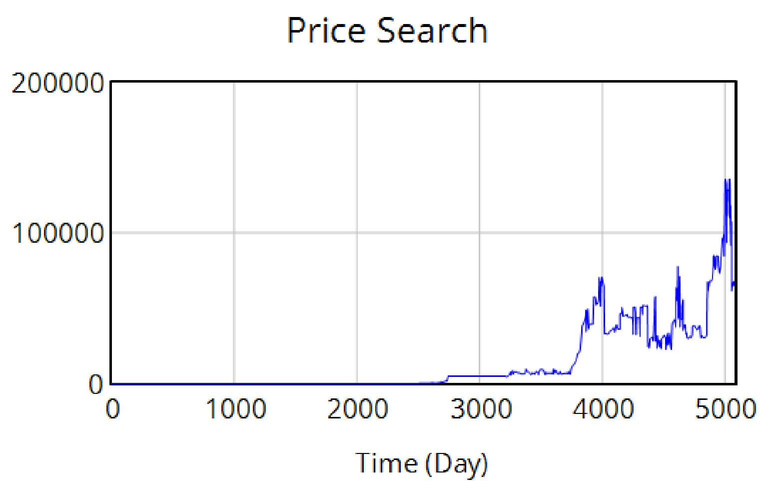
Figure 2: Vensim simulation model

Figure 3



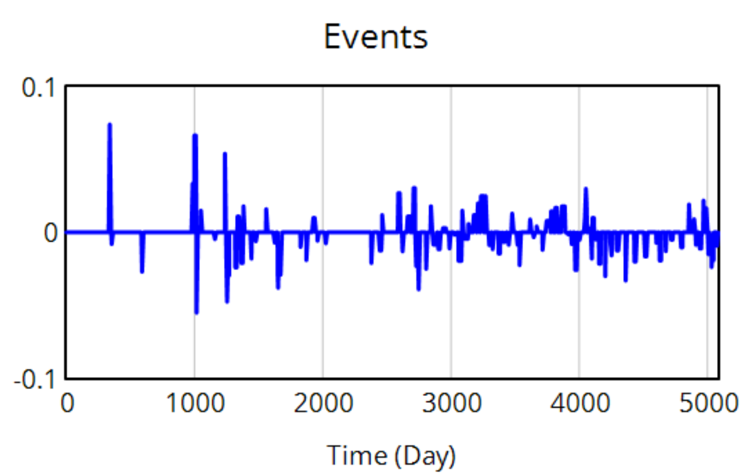
Cumulative Supply Graph

Figure 4



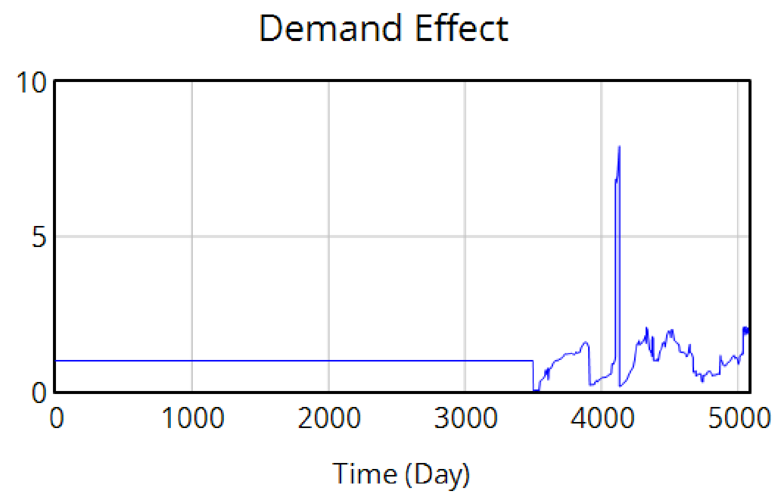
Search based on price output

Figure 5



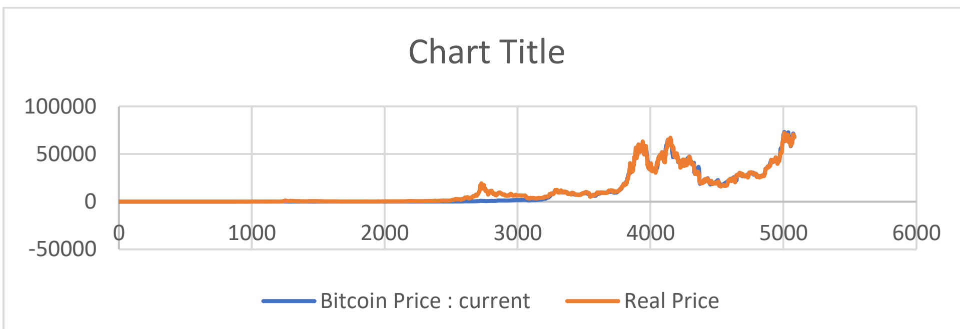
Impact function of events effect

Figure 6



The demand function that affects the price rate

Figure 7



Simulation Graph

HOW TO CITE THIS ARTICLE:
Sharafian Ardekani,R, Daneshvar A, Madanchi Zaj ,M, Rahnamaroodposhti, F, (2024). Modeling and Simulation of the Bitcoin Price by the System Dynamics Method, International Journal of Finance, Accounting and Economics Studies, 5(3): 1-18.
Journal homepage: https://sanad.iau.ir/journal/ijfaes