Economics Project

Theme's choice motivation: We chose this topic given the increasing importance of an alternative money 'system' to the one that has always been used, paper and metal (also called 'Fiat Currency'). In the last few years, this topic has been talked about very often, not only 'in the streets' but also in the media.

'Cryptocurrencies, an Alternative to Fiat Currencies?'

ABSTRACT – Cryptocurrencies, a novelty in our economy. The advent of an opportunity in economics to consider a fundamentally novel good that requires some reconsideration or restatement of basic economic theory is rare. Cryptocurrencies are such a novelty good that forces us to rethink money and monetary policy. The aim of this report is to study the possibility of cryptocurrencies becoming an alternative to fiat currencies. Therefore, for simplicity reasons, it is assumed that cryptocurrencies can be viewed as a "currency", which can be highly debatable. Therefore different scientific papers and books were studied to conclude that there are two major challenges holding cryptocurrencies back to become a valid alternative; the volatility and the power-intensive mining process.

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Date: May 14, 2021

University: Instituto Superior Técnico

Course: Economics

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1. Introduction

1.1. What are Cryptocurrencies?

Cryptocurrencies are digital currencies that are secured by cryptography, making it almost impossible to counterfeit. Many cryptocurrencies use block chain technology, on which every transaction has to be validated in order to enter the chain. Each block of the chain contains a certain number of transactions, and each block has a unique hash value (numeric value which identifies data) that depends on the hash value of the previous block; this maintains the integrity of the block chain.

Any user can act as an "auditor" and validate transactions using the computer power of hardware, and for that the user hardware must validate the transactions and guess the hash code of that block, the first user to reach the solution receives a certain amount of that cryptocurrency (block reward); this process is called "mining". Because only the fastest user to guess the hash code gets the block reward, if there's a big amount of users mining, it's likely that only the users whose hardware has a bigger processing capacity get the block reward.

Some cryptocurrencies have a maximum limit of supply, meaning that the total supply of that cryptocurrency can't exceed the limit. When that happens, there are no longer block rewards and there can't be new coins in the market, however there can still exist transaction fees, in order to promote the mining activity to keep the integrity of the blockchain.

There were some attempts to create online currencies, for example B-Money (formulated by Wei Dai in 1998) and Bit Gold (proposed by Nick Szabo also in 1998), but those were not fully developed.

Bitcoin (BTC) was the first cryptocurrency to be created. The creator was Satoshi Nakamoto, which is a pseudonym for an individual or a group of people whose identity remains unknown. The concept was firstly presented in a paper in 2008, and Bitcoin started supplying in 2009. In the first months after its creation, it was only possible to obtain Bitcoins through mining, until the first economic transaction of Bitcoin, which happened in May 2010, when a man exchanged two Papa John's pizzas, valued at $25, by 10000 bitcoins.

Given the increasing popularity of Bitcoin, and the appealing idea of encrypted and decentralized currencies, other cryptocurrencies emerged. Given its decentralized nature there's no official data for the number of cryptocurrencies, however a website that claims to be the most reliable source of cryptocurrencies tracking is listing 5017 cryptocurrencies with a total market capitalization of more than €1.9 trillion.

The market

In May 9th, 2021, the cryptocurrencies with the biggest share of the total market capitalization (sum of the market capitalization – circulating supply multiplied by the reference price of the respective cryptocurrency - of each tracked cryptocurrency) were the ones that can be seen in Table 1 (CoinMarketCap, 2021).

Table 1 Top 10 of cryptocurrencies with the biggest Market Cap.

#	Name		Price	Market Cap	% of Market Cap (s_i)
1	Bitcoin	BTC	€ 47,343.11	€ 885,454,462,638	44.4766%
2	Ethereum	ETH	€ 3233.92	€ 375,418,295,517	18.8574%
3	Binance Coin	BNB	€ 544.82	€ 83,613,668,882	4.1999%
4	Dogecoin	DOGE	€ 0.40	€ 51,462,344,208	2.5850%
5	Cardano	ADA	€ 1.48	€ 47,270,610,210	2.3688%
6	Tether	USDT	€ 0.82	€ 45,667,072,417	2.2939%
7	XRP	XRP	€ 1.24	€ 43,582,483,824	2.1840%
8	Polkadot	DOT	€ 32.85	€ 30,695,872,686	1.5419%
9	Bitcoin Cash	BCH	€ 1,106.76	€ 20,757,515,308	1.0402%
10	Litecoin	LTC	€ 298.36	€ 19,985,448,571	1.0015%

As it can be seen in the table, Bitcoin is still the cryptocurrency with the highest market capitalization, followed by Ethereum (ETH) and Binance Coin (BNB).

If we consider cryptocurrencies to be a market itself, we can calculate the concentration index (C) and the Herfindahl index (H) in order to evaluate the concentration of the various existing cryptocurrencies.

Taking into account the percentage of the total market capitalization of the top 100 cryptocurrencies in Market Cap, we can estimate the indexes C and H for the market.

Considering the figures of May 9th, 2021, the main C_k index values are the following:

$$C_1 = 44.4766\,\%$$

$$C_2 = 63.3340\,\%$$

$$C_7 = 76.9656\,\%$$

$$C_{100} = 97.2968\,\%$$

By analysing these figures, it's noticeable that the cryptocurrency with the biggest market cap. share (BTC) has almost 45% of the total market cap., while the two biggest cryptocurrencies represent, in total, more than 60% of the total market cap, and the 7 biggest cryptocurrencies have almost 77% of total market cap. share. Considering that the biggest cryptocurrency represents almost half of the entire market, the top 2 cryptocurrencies represent almost 2/3 of the market, and from the 10th biggest cryptocurrency all of them have less than 1% of market cap. share each, we can deduct that the market

structure is similar to one with a dominant "firm" and a competitive fringe. It's also relevant that the top 100 cryptocurrencies represent almost the whole market cap. (around 97.3%).

Regarding the Herfindahl index, as the top 100 cryptocurrencies represent more than 97% of the market, it's considered only the market cap. shares for those currencies and then the method taught in class is applied to estimate the market shares of the supposed currencies with lower market share.

The Herfindahl index is equal to 0.2384, which means that if it was a market of firms, it would be an oligopoly because the index is higher than 0.2, however this market structure is close to a perfect competition.

The Adelman number for this market is 4.19, which means that in a hypothetical situation in which all cryptocurrencies have the same market capitalization and H=0.2384, there would exist only around 4.19 currencies. The market has more than five thousand currencies, so, this Adelman number means that there are currencies that have a bigger market cap. share and others that have a smaller market cap. share compared with what would happen if every currency had the same market cap. share when considering the same value of H. This enhances the argument that this market is composed of a dominant currency (or a few dominant currencies) and a competitive fringe that is composed of numerous currencies with a small market cap.

Examples of cryptocurrencies

Some examples of cryptocurrencies are Bitcoin (BTC), Ethereum (ETH), Monero (XMR) and Pirate Chain (ARRR).

As stated earlier, Bitcoin (BTC) was the first cryptocurrency to be created, and despite facing an increasing competition with many other cryptocurrencies, it's still the most used cryptocurrency with a market cap. share of almost 45%. There's a supply limit of 21 million bitcoins, and currently the block reward is 6.25 BTC, but every four years[1] it's halved, meaning that the block reward is reduced by half.

Ethereum was first proposed in 2013 by Vitalik Buterin and was first launched in 2015. The main difference compared to Bitcoin is that, while Bitcoin is just a cryptocurrency, Ethereum is not just a currency, as it also has other applications such as making smart contracts or decentralized apps (Dapps). The cryptocurrency used in Ethereum is called Ether (ETH), and, unlike Bitcoin, this currency doesn't have limited supply.

Monero (XMR) is a cryptocurrency that was created by a person who identifies him/herself as "thankful_for_today" and was launched in April 2014. It's based on the CryptoNote technology, that ensures more privacy in the block chain nodes, namely the impossibility of detecting who are the sender and the receiver on the transactions, and only an approximation of the amount of the transaction. After the creator of Monero proposed controversial changes, a team of people (Monero Core Team) forked the project and is now overseeing the cryptocurrency with the help of the community.

Pirate Chain (ARRR) is a cryptocurrency that was created in 2018 by a group of people from a community in Discord who aimed to create the most private cryptocurrency in the market. This

[1] Estimated time. On Bitcoin, halving occurs every 210000 blocks.

cryptocurrency has more privacy than other private cryptocurrencies since it uses the Zk-SNARKs[2] protocol, which allows the transaction being verified without revealing any information regarding it, only the user has access to his/her wallet information and balances. This cryptocurrency has a supply limit of 200 million and the reward halving (block reward cut in half) occurs approximately every 270 days.

Pirate Chain had a massive surge in popularity in April 2021, probably due to the enhanced privacy when compared to other currencies like Monero.

Table 2 Main figures for BTC, ETH, XMR and ARRR

	BTC	ETH	XMR	ARRR
Max. supply	21 million BTC	--	--[3]	200 million ARRR
Block time	10 minutes	13.2 seconds	2 minutes	60 seconds
Block reward	6.25 BTC	5 ETH	4.99 XMR	32 ARRR
Reward halving (approx. days)	1460	--	--[3]	270

1.2. Fiat currency

Fiat currency, or also known as fiat money, can be defined as a government-issued currency that is not backed by physical commodities, such as gold or silver, but rather by the government that issued it. It is any legal currency that is not backed by a physical commodity, nor does the material it is made of has any significant value. Its value is derived from the relationship between the supply and the demand as well as the stability of the issuing government. The term fiat actually derives from Latin and means "It shall be", showing that the government agreed that "it shall be" a legal tender. Examples are the euro, the U.S. dollar and other major global currencies. Currency that is backed up by commodities is known as commodity money / representative currencies, like gold or silver. Which limits governments to only theoretically create as much currency as it had gold or silver in its value (Chen & Anderson, 2021).

Fiat currencies became the norm in 1971 when the US President Richard Nixon declared that the U.S. Dollar was no longer convertible into gold. Fiat money gives central banks a greater control over the economy since it is not a fixed nor scarce resource like gold. It gives them the power to manage economic variables such as the amount of money that is printed (credit supply, composed of intelligent management of money supply), as well as interest rates, liquidity, and money velocity. Within this new set up which includes fiat currencies the economic principle 7 is clearly applied "Governments can sometimes improve market outcomes".

However, since fiat money is not linked to physical reserves it risks losing value due to inflation or even becoming worthless in the event of hyperinflation. Hyperinflation will occur when governments print too much money, which can result in a huge decrease of value, which is in line with economic principle 9 "Prices rise when the government prints too much money". Another danger is if people lose faith in a nation's currency, the money will no longer hold value. An example is the mortgage crisis of 2007 and subsequent financial meltdown, which demonstrates the effect of expected inflation.

[2] Zero Knowledge-Succinct Non-interactive Argument of Knowledge

[3] Monero will have two main emissions: firstly will be supplied around 18.132 million coins by the end of May 2022 (block reward decreases gradually), then, after the first emission is done, the coins will be supplied at the rate of 0.6 XMR per 2-minute block (block reward is 0.6 XMR). (Monero Supply, 2021)

These events affected the belief that central banks are able to prevent depressions or serious recessions by regulating the money supply.

2. Impact of cryptocurrency on economy

2.1. Commodity or currency

The biggest fundamental question is if cryptocurrencies can be seen or treated as a currency or as a commodity (good/services). It is known as crypto“currency”, indicating it to be a currency. However, it isn’t always easy to treat crypto like other currencies, “Money is defined as a medium of exchange, widely used, which crypto isn’t yet – David Beckwordt, former economist at the US Department of Treasury” (Subramanian, 2021). Cryptocurrencies often behave more like a speculative asset, instead of being used to purchase things. The face value of a single bitcoin changes wildly in short periods of time, depending on how much people want to buy it, just as with risky stocks in an exchange. The result is the exceptional “token” or “coin” which is not yet fully adapted and lacks a clear role in our economy. It would however greatly affect the way it is being handled within our economy, and its effect on the economy as a whole. For example, it would only consider the GPD, the GDP deflator and the CPI if it were considered a “commodity”, not a currency.

This is a current debate amongst experts and only the future might tell what kind of asset it will become.

2.2. Market characteristics

The cryptocurrency market can be considered:

- …as one of free trade. The main objective of the block chain technology, the holy grail behind cryptocurrencies, is to exclude any mediators (e.g. banks) between transactions and set up a decentralised model. Therefore, the coins can be traded freely worldwide.
- ….as one which includes respect of property rights/ownership. Once you invest an x amount of monetary units you acquire an y amount of coin/token. The currency’s value can vary widely as cryptocurrencies are considered highly volatile.
- …as a market that includes its own common currency area (CCA), theoretically speaking it is all traded within U.S. Dollars, and therefore forms its own CCA “bubble”.
- …as one without protectionism, there is no tariff or quota when it is traded since it is traded digitally and does not cross actual “physical borders”, however a form of transactional expense would advent and to be known as mining expenses / mining transaction costs when the finite number of the amount of coins is reached.
- …as a market with finite supply, an inelastic supply. For example, Bitcoin has a finite supply of 21 million coins, expected to be reached by 2140 or so, based on the mining algorithms (Putman & Norland, 2018).
- ... is resistant to "inflation" as cryptocurrencies in general have a finite supply. This limited supply allows bitcoin to withstand inflation. In the bitcoin world, the term inflation is not used as economists do (the change in the CPI over time) but tends to use it to indicate an increase in the money supply. This is in line with the supply and demand theory.

- as a market with high volatility, typically with markets with an inelastic supply, are known for their higher volatility. That's a huge challenge for cryptocurrency to actually become an alternative to fiat currencies. This is further elaborated in section 4.1.

2.3. Influence on Global Financial Markets

There are three main players within the cryptocurrency market; individual investors around the world (1), various global companies (2) and finally governments worldwide which are beginning to police cryptocurrencies (3). However, the effect of cryptocurrencies on the Global Financial Markets is still quite small when compared to the market as a whole. Bitcoin accounted for approximately 0,4% of the world's broad money supply (as of March 4, 2020) (Reiff, 2020).

The individual investor's response to the advent of cryptocurrency has shown it is being used as an add-on of diversified portfolios for two reasons, either as a means of speculation (1) or as a hedge against a large-scale financial crisis (2). Which is similar to how one might invest in precious metals such as gold. Whereas it can be argued that cryptocurrencies are seemingly easier to acquire, hold and transact than gold, making it truly revolutionary.

Cryptocurrencies can be used in order to protect the assets from extreme inflation and out of control spending by the government e.g. in Venezuela, or to get the assets out of the country e.g. in China, or as an alternative to cash to avoid government regulation e.g in India. Cryptocurrencies are banned in all three of these countries (Venezuela, India and China). This extreme government response shows the fear that decentralized currencies invoke. Countries are showing different responses regarding the growing importance of cryptocurrency by either trying to curb its adoption or embracing it by looking for ways to incorporate the technology into their own fiscal methods (or both at the same time). More regarding regulations can be found in section 3.

The reputation of cryptocurrencies is shifting and seen by the public as cutting-edge technology. The market demands that forward-thinking companies integrate cryptocurrency. Where in the past it was stated in many articles that cryptocurrencies were not seen as a payment method, that has now changed. As we know today, there are many companies that incorporate cryptocurrencies as a payment method, including nine major companies. Just to name a couple: Microsoft and Home Depot accept bitcoins as a payment method. Giving it a value and purpose within the economy (Tuwiner, 2021).

At this point, it can be concluded that cryptocurrencies are not direct challengers of centralized currencies or the stock market. On the contrary, it is something that coexists with these traditional markets, which enforces again its similarity to gold. The numerous advantages of cryptocurrencies over various centralized currencies will drive the growth of this industry. And it is growing rapidly, since January 2021 it is now considered the fifth most circulated currency. It outstrips the sum of coins and bills in circulation in major economies such as India and the UK, until a new cycle of volatility spirals it down again (Subramanian, 2021).

In essence, cryptocurrencies provide a transparent and inexpensive payment platform that allows money to be sent at a lower cost and in less time compared to centralized currencies. However, the existence of an alternative asset such as cryptocurrency in times of economic hardship can counterbalance a government's efforts to stabilize their own centralized currency or to control the assets of the public as these cryptocurrencies are out of reach and can only be influenced indirectly (Simonovsky, 2018).

Some experts have raised concerns about the inclusion of highly volatile cryptocurrencies in diversified portfolios, exposing global markets to high risk in the event of cryptocurrency prices crashing. For now, this risk is very small, as cryptocurrencies make up only a very small part of the global money supply.

When taking into account the economic principle 6 “Markets are usually a good way to organize economic activity”, it can be believed that when cryptocurrencies have established a clear market, it can manage its own economic activity, including its equilibrium.

2.4. Possibility of price ceilings and price floors by government.

A Price Ceiling is the mandated maximum amount a seller is allowed to charge for a product or service. Usually set by law, price ceilings are typically applied only to staples such as food and energy products when such goods become unaffordable to regular consumers.

Having said this, cryptocurrencies do not have Price Ceilings, at least for now, as there is no mandated maximum amount to be charged for the acquisition of cryptocurrencies. The same reasoning is applied regarding price floors, which means that, for now, governments do not have a say in the minimum price that a cryptocurrency can be bought at.

If governments around the world start having control of the cryptocurrency markets, namely through regulations, as described in section 3 below, then it is possible that they would create Price Ceilings and Price Floors, influencing the amount at which people who use cryptocurrencies can buy or sell their coins. This would go against the whole purpose of having decentralised money.

3. Regulation regarding cryptocurrency

In this section, some of the regulations of cryptocurrency that exist today around the world will be analysed. With the increasing demand and use of cryptocurrencies, governments in all countries are trying to create regulations and legislations in this matter.

The word “cryptocurrency” may be used differently in many countries, according to their respective legislatures. For example, “digital currency” is used in Argentina, Thailand and Australia, “virtual commodity” is used in Canada, China and Taiwan, “crypto-token” is used in Germany, etc.

Governments around the world, in order to educate their citizens about the risks of investing in cryptocurrencies, issue warnings noticing that people who (want to) use cryptocurrencies evaluate its volatility, uncertainty and lack of regulations.

Many of these warnings warn the possibility that cryptocurrencies may enable counterterrorism, money laundering and other related crimes. Some jurisdictions do impose restrictions on investments in cryptocurrencies, varying from country to country.

Some countries ban all activities involving cryptocurrencies, some bar their citizens from engaging in any kind of activity related to cryptocurrencies locally but allow them to do so outside their borders while others, even if not banning their citizens from investing in cryptocurrencies, impose indirect restrictions by barring financial institutions within their borders from facilitating transactions involving cryptocurrencies.

One way that governments can regulate the transactions made using cryptocurrencies is through taxation. The problem with taxation is that the gains made from mining or selling cryptocurrencies would have to be categorized as income or capital gains, and this will determine the tax bracket.

Here are some countries that have categorized cryptocurrencies differently for tax purposes:

- Israel: taxed as asset
- Bulgaria: taxed as financial asset
- Switzerland: taxed as foreign currency
- Argentina: subject to income tax
- Denmark: subject to income tax and losses are deductible
- United Kingdom: corporations pay corporate tax, unincorporated businesses pay income tax, individuals pay capital gains tax.(1)

4. Challenges / issues

4.1. High volatility

One of the issues of the cryptocurrencies is the high volatility of those compared to the fiat currencies. In order to assess the volatility of cryptocurrencies, it was calculated the volatility of the cryptocurrencies that are being analysed on this project (BTC, ETH, XMR and ARRR) and some of the most important fiat currencies (USD, JPY and GBP). Euro (EUR) was used as a reference, since the volatility was calculated in relation to the EUR currency. Regarding XMR and ARRR, there's only available data since 2019.

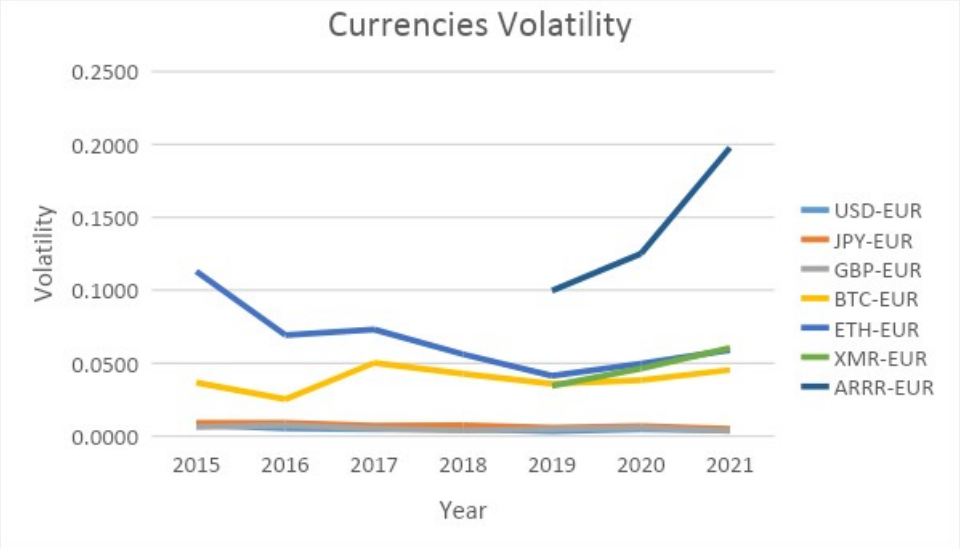

Figure 1: Volatility of fiat currencies USD, JPY and GBP and cryptocurrencies BTC, ETH, XMR and ARRR in relation to EUR.

In Figure 1 it's noticeable that the most volatile cryptocurrency among the ones that are being analysed is Pirate Chain, however the fact that its value increased a lot in April 2021, followed by a fall (Laybourne, 2021), which makes the volatility to increase. We can also conclude that, although the general trend of the volatility of cryptocurrencies is to decrease and some arguments that say that Bitcoin volatility could reach the volatility of fiat currencies (Cermak, 2017), there was a slight increase in volatility from 2019 until 2021. When the volatility of fiat currencies is compared with volatility of cryptocurrencies in the figure, it's noticeable that the volatility of fiat currencies is considerably lower than the one of cryptocurrencies, and that can result from several factors, either internal or external, that can be seen in Figure 2.

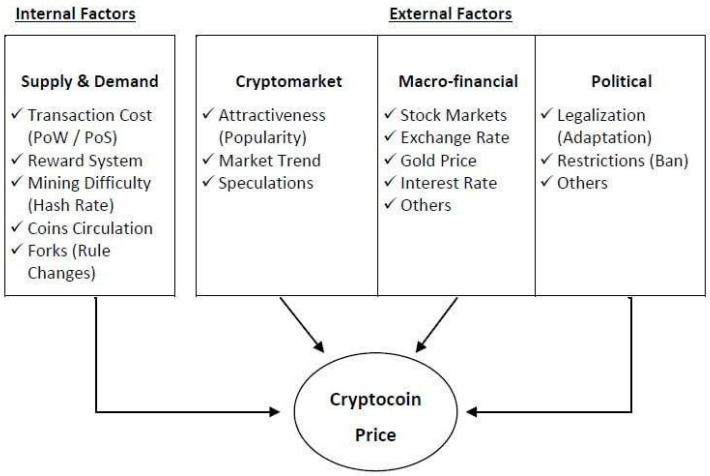

Figure 2: Factors that affect Cryptocurrencies price (Sovbetov)

Despite the internal factors, namely supply and demand, are the ones that have more influence in the market price, there are also external factors that affect the market price of cryptocurrencies. Regarding the crypto market, the popularity of cryptocurrencies can affect their price, for example, Dogecoin (DOGE), which was created as a joke currency based in the 'Doge' meme, is now one of the most valuable cryptocurrencies due to its popularity (Nishida, 2021). Regarding the Macro-financial factors, the fact that cryptocurrencies are expected to be accepted as a payment method or not can also influence its price, for example, Tesla announced that it would begin accepting cryptocurrencies as a payment method, which caused the value of Bitcoin to grow, however some weeks later, Elon Musk announced that Tesla would stop accepting cryptocurrency payments due to its potential environmental issues.

Other potential issues that may cause the increase in the volatility of cryptocurrencies are regulatory and/or law issues due to decisions from the Governments or the Central banks, who may take decisions in order to restrict or tax cryptocurrency transactions, or in the opposite direction, by enhancing cryptocurrencies as a legitimate part of the financial system. This can cause a decrease or an increase, respectively, of the perceived intrinsic value of cryptocurrencies, potentially affecting the market price of cryptocurrencies.

4.2. Mining

4.2.1 Economic aspects of mining cryptocurrencies

For cryptocurrencies there is another economic aspect to look at, namely the computational supply and demand. Cryptocurrencies are very computation and thereby energy intensive, which will be explored hereafter. In this chapter, we will have a look on the micro-economic level into the so-called cryptocurrency mining with the example of Bitcoin.

First of all, it is important to understand some basics of cryptocurrencies and blockchains. As already mentioned, transactions of cryptographic currencies are stored in blocks of the blockchain. In the example of Bitcoin a block contains usually around 2000±500 transactions (Average Transactions Per Block, 2021). Bitcoin miners are computers (usually arrays of them) that try to solve an equation to find a unique hash (unique number) that closes the block. The equation can only be solved by computing with random numbers until a matching result is found. This task requires an enormous number of computations, which is undertaken by the whole mining network simultaneously. The owner of the machine that solves the equation is rewarded with a certain number of Bitcoins for the effort. This amount currently equals 6.25 BTC or $357,850 (9th of May). The Bitcoin algorithm contains an auto-adjustment that adjusts the difficulty, or the effort needed to solve the equation proportionally to the available computing performance of the network. This in fact means that the Bitcoin mining converges to a mean of 1 mined Bitcoin every 10min or 144 in one day worldwide. This feature is important for further economic analysis.

The mining and the underlying computational power is essential to maintain the cryptocurrency by enabling transactions. For the mining market, Bitcoin could instead as a currency be regarded as a digital commodity. Generally, the mining market is a competitive market, where individuals or firms can participate or exit. For such a market, the equilibrium would be if the average total cost matches the marginal cost. A firm in such a competitive market would additionally try to maximize profits to reach the point where the marginal revenue coincides with the marginal costs. If the Bitcoin price rises, it would be expected that miner profits will rise, however, the produced quantity of Bitcoins will not. This has two reasons: Firstly, the computational power supply is very inelastic as it takes time to set up new “computer farms”. Secondly, the mining difficulty will adapt with additional available computing power to counteract mining of additional Bitcoins. In the long-run, new entrants will enter the mining market and existing players will expand their capacities. Simultaneously, the mining difficulty will adapt until a new equilibrium is reached. This correlation can be seen in Figure 1.

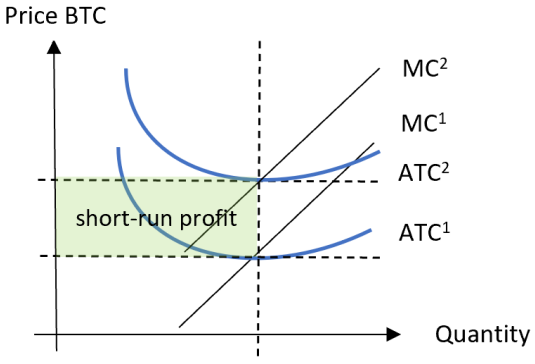

Figure 1 Price increase with long-run equilibrium

Now, this correlation will be investigated with real-world data. To apply these micro-economic mechanisms, a formula was derived by Hayes to describe the equilibrium between revenue or mining rewards on the one hand and equipment and variable cost (simplified electricity cost) on the other hand (Hayes, 2015).

$$W\ per\frac{GH}{s}=\frac{P(BTC)/day}{P(kWh)\cdot 24\,hr_{day}}$$

The left side of the formula denominates the energy consumption per unit of computational power (energy efficiency). The right side of the equation contains the average mining reward that is attained for the unit of computational power invested for a period of 24h as well as the price of the variable cost for the same time interval.

In the following part we will calculate the maximum sustainable electricity cost for different values of Bitcoin to understand the underlying market dynamics. To apply the formula, some assumptions and simplifications need to be established. The true average energy efficiency of the network is unknown and cannot be retrieved. For the sake of simplification, it will be assumed to be the same as the equipment that is assumed as the basis for the computations. In other words, it will be assumed that the whole network consists of the same uniform equipment which is in reality not true. Additionally, values from literature have to be taken to know the fraction of lifetime fixed cost to lifetime total cost for a mining computer (Vries, 2016). Also, additional revenue from transaction fees is neglected.

For example, a machine from literature (Barclay, 2018) is used for the calculation. The key data W/GH, efficiency and GH/s for the “Antminer S9” can be found in Table 3.

Table 3 Parameters for calculation

Ratio variable/total cost		0,33
BTC/(day * GH)		5,92683E-05
kWh Price [$]		0,05
W/GH	Antminer S9	0,096296296
efficiency		93%
GH/s		13500
BTC difficulty: H/BTC	1,42361E+18	10. Mai
	2,99E+17	2018
BTC reward/block	6,25	10. Mai
Specific revenue: BTC/GH	9,48293E-06	10. Mai
	4,52E-05	2018
Specific time to solve one block [days]	105453	10. Mai
	22119	2018
Specific time to solve one block [years]	289	10. Mai
	61	2018

The mining revenue in Bitcoins per day and GH (giga hashes) is calculated taking into account the mining difficulty as of the 10th of May in the unit of average hashes required to mine one Bitcoin and the current reward in Bitcoins per solved block (see table 3). From these numbers the specific revenue for the "Antminer S9" can be obtained, as well as the specific time to solve one block in days and years, which is 105,453 days or 289 years, respectively. Data for 2018 are only shown for information and were used to validate the calculation against the ones found in the literature.

Table 4 Maximum kWh price for different values of Bitcoin

Price BTC [$]	kWh Price [$]
58879	0,47
50000	0,40
40000	0,32
30000	0,24
20000	0,16
17119,65	0,14
10000	0,08
5000	0,04
4000	0,03
3000	0,02
2000	0,02
1000	0,01

The computational results can be found in table 4. We can see that for the current BTC value of $58,879 (10.05.2021 20:29 GMT+0) the equilibrium kWh price would be $0.47. To set this into relation a realistic price per kWh in Portugal would be around $0.14 (Lojaluz, 2021)and the price per kWh for Chinese farms in inner Mongolia is estimated to be around $0.04 - $0.05 (Bitcoin Electricity Consumption: An Economic Approach, 2017). We can see that the market is currently not in equilibrium as the equilibrium price per Bitcoin for a mining computer in Portugal would be around $17,119.65 (see figure 1). This can be explained by the recent rise in the Bitcoin price and that the computational supply has not yet adapted to the new price. It can be expected that the computational performance of the network will rise due to the high attractiveness in the near future until in theory a new equilibrium is reached. However, the Bitcoin price is very volatile and it is unlikely that the equilibrium is ever reached in practice.

4.2.2 Ecological Aspects of mining cryptocurrency

As shown in the previous section, cryptocurrencies are extremely computing intensive. Depending on the algorithm behind there are significant differences between the currencies themselves. Therefore, Bitcoin and Ethereum will be analysed as they differ significantly in their energy consumption.

According to qualified estimations, the current energy consumption of the Bitcoin network is at around 114.675 TWh annually. To understand the enormous number, it has to be embedded in the context of the annual energy demand of whole countries. By doing that Bitcoin would currently range in between Kazakhstan (97.6 TWh) and the Netherlands (117.1 TWh). Portugal in comparison has an annual consumption of 46.94 TWh of electricity. As a substantial part of the mining is taking place in carbon intensive countries such as China, the CO2 equivalent emission of Bitcoin mining accumulates to 54.18 Mt. If broken down to energy consumption per transaction, this equals 1119.48kWh per single transaction, which is in the magnitude of the annual electricity consumption of a household (7).

Ethereum is the second biggest cryptocurrency in regard to market capitalisation as shown before. The whole computing network behind Ethereum is believed to consume annually 44.95 TWh of electricity. Thereby, it ranges close to the energy demand of Angola or Honduras and is just slightly lower than the electricity consumed in Portugal per year. As Ethereum is using a different architecture for its blockchain, the electricity demand is drastically lower as for Bitcoin with an estimate of 82.16 kWh, which is still magnitudes higher than a transaction of any conventional fiat currency (Bitcoin Energy Consumption Index, 2021).

From these enormous numbers it can be easily seen that from a sustainability point of view efforts are crucial to make cryptocurrencies several magnitudes more energy efficient if the number of transactions will continue to increase.

5. Conclusion

In this study the goal was to analyse the cryptocurrency market and evaluate the possibility of being an alternative to fiat currencies. Some constraints to the project were the fact that many of the scientific papers about the topic were made about three years ago, as well as not having centralized information about the characteristics of each cryptocurrency.

Cryptocurrencies were created in order to provide an alternative currency system that is not under direct influence of the Governments and Central banks and is decentralized, leading to the monetary “policies” of cryptocurrencies not being under only one or a few organizations but within a community of people. The fact that the entry barriers to new cryptocurrencies are lower than the ones for fiat currencies (that depends almost entirely on political decisions) also provides a higher freedom of choice both by the investors (from the big investors until the average citizen) and the businesses to opt to invest or paying/providing payments in different currencies.

Cryptocurrency is still in its early stages of development, but its existence has been raising concerns from the Governments and Central banks, due to the possibility of being widely used and reducing the importance and usage of fiat currencies, which could affect the financial system. On the other side, the supporters of cryptocurrencies say that cryptocurrencies are going to be widely used in the future, due to its transparency, decentralization and fairness.

Currently, Bitcoin's volatility makes it difficult for producers and consumers looking to make a living. As retailers begin to accept Bitcoin for goods and services, it is unlikely that they are excited about holding something volatile. Therefore, the volatility of the current cryptocurrencies can be seen as their drawback of becoming an alternative to fiat currencies. As well their huge energy consumption is an obstacle to be addressed for scalability. Depending on the cryptocurrency, enhanced privacy can be both an advantage, because it prevents from excessive surveillance over the person or organization’s money, and a disadvantage, since it can increase illegal activities such as money laundering or

terrorism financing, and in the case of someone's money is stolen or caught in scams, it's impossible to recover it.

Nowadays, cryptocurrencies are mostly used as a means of speculation, a hedge against crisis in centralized currencies, or as a means of protection from government influence and high inflation. It is, however, advisable to learn from the benefits of cryptocurrencies and perhaps adapt them into the financial models that exist in our economy.

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7. Appendixes

7.1. Calculation of H index

$$\%\ of\ market\ cap\ .\ share\ known = \sum_{i=1}^{100} s_i = 97.2968\,\%$$

$$H_{min} = \sum_{i=1}^{100} (s_i^2) = 0.2384$$

$$\%\ of\ unknown\ market\ cap\ .\ share\ known = 100\,\% - 97.2968\,\% = 2.7032\,\%$$

$$s_{100} = 0.05\,\%;\ next\ currencies\ with\ 0.04\,\%$$

$$\frac{2.7032\,\%}{0.04\,\%} = 67.58\ currencies$$

67 currencies with 0.04% and 1 currency with:

$$2.0732\,\% - 0.04\,\% * 67 = 0.0232\,\%$$

$$H_{max} = H_{min} + 67 * 0.04\,\%^2 + 0.0232\,\%^2 \approx 0.2384$$

$$H_{min} = H_{max} = H = 0.2384$$

7.2. Calculation of Adelman number

$$A = \frac{1}{H} = \frac{1}{0.2384} \approx 4.1944$$

7.3. Volatility calculation methodology

In order to calculate the volatility, it was collected the exchange rate (price) history data for the pairs BTC-EUR, ETH-EUR, XMR-EUR, ARRR-EUR, USD-EUR, JPY-EUR and GBP-EUR

Then it was calculated the return for each daily closing exchange rate available on day i (P_i), using the formula:

$$\frac{P_i - P_{i-1}}{P_{i-1}}$$

Then, Microsoft Excel was used to obtain the volatility by calculating the standard deviation of the set of returns of the days from each civil year (e.g. for 2021 it was calculated the standard deviation of the returns of the days of year 2021).

The numeric figures for the volatility for each year can be found in Table 6:

Table 6: Volatility values for a selection of fiat currencies and cryptocurrencies in relation to Euro

Currencies/ Year	2015	2016	2017	2018	2019	2020	2021
USD-EUR	0.0077	0.0053	0.0046	0.0045	0.0032	0.0047	0.0038
JPY-EUR	0.0089	0.0090	0.0072	0.0074	0.0057	0.0067	0.0048
GBP-EUR	0.0062	0.0073	0.0051	0.0038	0.0048	0.0057	0.0036
BTC-EUR	0.0367	0.0253	0.0502	0.0426	0.0358	0.0382	0.0453
ETH-EUR	0.1130	0.0692	0.0730	0.0561	0.0413	0.0496	0.0589
XMR-EUR	--	--	--	--	0.0344	0.0462	0.0604
ARRR-EUR	--	--	--	--	0.0997	0.1251	0.1978