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Empirical Evidence Regarding Implications of Crypto-Assets Energy Usage on Climate

Abstract. *The crypto market is increasing every year in terms of crypto-assets issued and market capitalisation. Bitcoin remains the most known and tradable crypto-asset from this ecosystem and together with other crypto-assets have significant carbon footprint, being estimated in the current academic literature to be similar to the one of some medium size countries, such as Argentina, Egypt, Spain, the Netherlands or Austria. These facts are considered to affect the valuation of these crypto-assets and also the future of crypto-assets that use protocols with significant carbon footprint. In our paper we tried to present some possible policy options for prudential regulators and for authorities, that aim to raise concerns regarding climate-related considerations in crypto investors' practices. Our findings showed that climate policy uncertainty affects directly the profitability of mining activities and this is leading to a decrease in the overall hash rate of the Bitcoin network, with direct and severe implications on the security and reliability of the network. Meanwhile, our result showed that GPEI's decrease has a positive impact on Bitcoin prices, respectively, which would make Bitcoin mining and operation profitable, as energy cost is one of the most significant costs for mining activities.*

Keywords: *crypto-assets, energy consumption, Bitcoin, mining, carbon footprint.*

JEL Classification: G28, O36, O38, C01.

1. Introduction

Crypto-assets are digital assets that are created, exchanged, and traded using new and innovative technology, such as blockchain (a decentralised, digital ledger system). The process of creating, exchanging, and performing transactions using crypto-assets, such as Bitcoin, Ethereum, and others, requires a significant amount of energy, which can have an impact on the environment. The energy consumption comes primarily from the process of "mining", which involves solving complex mathematical equations to verify and process transactions on the blockchain. To perform this process, powerful computer systems are required. These systems consume large quantities of energy, especially from fossil fuels. As crypto-assets are becoming more popular, at present around 7,000 crypto-assets being issued, the energy consumption and carbon footprint are also increasing. Bitcoin, the most known and trade crypto-assets, has a significant carbon footprint, reaching the annualised energy consumption similar to that of some mid-sized countries. In fact,

DOI: 10.24818/18423264/58.1.24.03

a study from the University of Cambridge estimated that the annual electricity consumption of the Bitcoin network alone is equal to the entire energy consumption of Argentina[1]. Another study carried out by the Cambridge Centre for Alternative Finance (CCAF)[2] says that Bitcoin mining uses about as much electricity as Egypt. A similar opinion has been published by the European Central Bank presenting the idea that the carbon footprint of some crypto-assets is estimated to be similar as the energy consumption of countries like Spain, the Netherlands, or Austria.

Figure 1 shows the country carbon footprint for Bitcoin, based on the country-level emission factors. Due to the limited availability of more recent data, the figure shows the emission levels between 2019-2021.

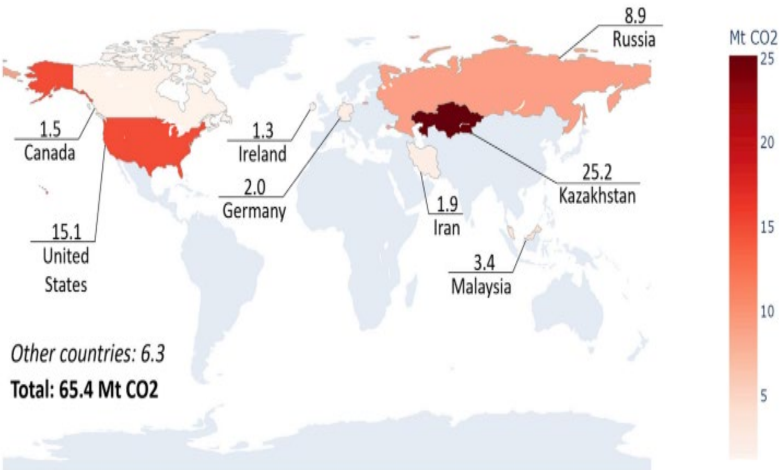

Figure 1. Estimated carbon footprint for Bitcoin (August 2021)

Source: Figure from the website of the Cambridge Bitcoin Electricity Consumption Index, which is constructed by the Cambridge Centre for Alternative Finance.

The climate impact of crypto-assets has become a growing and problematic concern, as the energy consumption and carbon footprint associated with their use contribute to climate change and the financial exposure to crypto-assets increased over the last years. According to the site coinmarketcap.com, in 2018 there were over 1,800 different types of crypto-assets and in 2022 they were around 6,500, of which 960 of those crypto-assets are mineable. Today, the market capitalisation of the crypto market is estimated at 6,17 billion USD.

In recent years, especially in the context of green policies, authorities have started to research methods through which they can promote the use of renewable energy sources for crypto mining and transactions, as well as the development of

1 "How bad is Bitcoin for the environment really?". Independent. 12 February 2021. Retrieved 15.

2 "Cambridge Bitcoin Electricity Consumption Index (CBECI)". ccaf.io. Retrieved 2 October 2022.

more energy-efficient blockchain technology. The first step has been made in this direction with the EU authorities issuing the EU Regulation Market in Crypto-assets (MiCA).

The direct relation between the valuations of crypto-assets using Proof of Work (mining)[3] and the jurisdictions' climate policies is foreseen in the near future. This consideration is also supported by the fact that countries started to look more closely into the use of different energy sources as a result of the recent spike in energy prices following the Russia-Ukraine war. In response to the studies published by the authorities and researchers showing the impact of crypto-assets to the environment, an entity representing the crypto ecosystem, Bitcoin Mining Council, published a paper presenting their opinion and argumentation on the Bitcoin mining impact on the environment. They sustain that Bitcoin uses a low quantity of energy due to the fact that it is rapidly moving to alternative energy sources, and is powered by a higher mix of sustainable energy than any major country or industry. The study was carried out based on information provided by 57 mining companies, representing 43.4% of the network.

Our paper is trying to present important elements in relation to the climate impact and transition risk of some crypto-assets. We tried to highlight potential policy responses from governments, authorities, and also issues to be considered by stakeholders when deciding to perform different types of activities in the crypto space or to add crypto in their portfolios. Additionally, the study provides an overview of the estimated carbon footprint of some crypto-assets and the elements causing this impact on the environment and highlights that there are possible alternatives with the potential to achieve similar results as the actual ones, but with less energy-intensive technologies. Finally, we present potential policy options that aim to mitigate the risk for the financial system as its exposure to crypto is significant, especially for those that have an important carbon footprint.

2. Literature review

When it comes to academic research, studies have evolved significantly in the last 10 years. At the moment, articles related to the volatility of crypto-assets, methods of handling these types of assets, or the possibility of considering them mediums of exchange (see R. Micu, Crypto-Assets Regime in the European Area (2021), Study regarding the volatility of main crypto currencies (2022), Volatility dynamics of crypto-assets (2022)) can be accessed. In recent years, academic literature identified studies on the usage of crypto-assets as payment method/currency and accepted by some merchants in commercial transactions. For example, G. Selgin (2014) showed that the acceptance rate of Bitcoin has been constantly increasing due to the involvement of traders who have accepted payments using Bitcoin. Also, he showed that more than 75,000 U.S. merchants accepted

[3] Proof of work (PoW) describes a consensus mechanism that requires a significant amount of computing effort from a network of devices.

Bitcoin as a payment method, which also proved to be a preferred medium for remittances from workers abroad. In 2020, we observe the fact that 36% of small and medium businesses in the United States of America accepted payments with Bitcoin. It is important to mention that there are some cases in which Bitcoin payments are accepted directly and others in which they are indirectly accepted. According to G. Pieters, S. Vivanco (2017), big and well-known merchants in the US (i.e., Wordpress.com, Reddit, Dell, Target, Expedia, Bloomberg, PayPal, and Tesla Motors) are accepting Bitcoin and the list continues to grow. In the case of Dell, they accept direct Bitcoin payments, but Amazon instead offers digital gift cards that can be purchased with Bitcoin and then used to purchase products from their website. A. Rogojanu and L. Badea (2014) presented evidence that in Cyprus, Canada, Romania, and other countries have installed ATMs for crypto, through which fiat currency can be converted into Bitcoin or Ethereum. Ş.Di Lek, Y. Furuncu (2019) conducted a study that indicated the existence of a number of 2,098 Bitcoin ATMs and altcoins in 62 countries. Compared to the total number of ATMs existing on the Globe (according to The World Bank – more than 3,5 million in 2020), crypto ATMs do not represent a significant number, but it shows that the interest for crypto is increasing. Moreover, it shows that the market requires access to similar services provided by traditional instruments, such as cards.

In the first quarter of 2023, according to https://www.blockchain.com, the number of confirmed transactions per day with Bitcoin reached 345,561 highlighting the interest of this crypto-asset as a way to transfer funds. In addition, according to https://www.blockchain.com, there are 19.32 million mined Bitcoins that are circulating. However, the number should be understood correctly considering that some Bitcoins are believed to be lost forever as users lost their crypto-wallet passwords. Moving to the subject related to the fees, we find evidence again on https://www.blockchain.com, that the fees increased in the last year from 6.36 USD to 37.34 USD (with an average fee per transaction of 11.49 USD).

Malone and O'Dwyer (2014) address the issue of Bitcoin by examining its profitability and come to the conclusion that while the Bitcoin exchange rate is decided by those who use it, it is also related to the price of electricity and how it is used. An important element is the problem of developing more energy-efficient hardware that is financially viable. The exchange rate between Bitcoin and other currencies fluctuates over time, similar to other assets. However, this also has an impact on the viability of Bitcoin mining, given that the value of a Bitcoin is less than the cost of the energy required to produce it. Therefore, mining no longer becomes efficient and the miners lose interest in the activity (the price of Bitcoin to US dollars for the last year is presented in Figure 2).

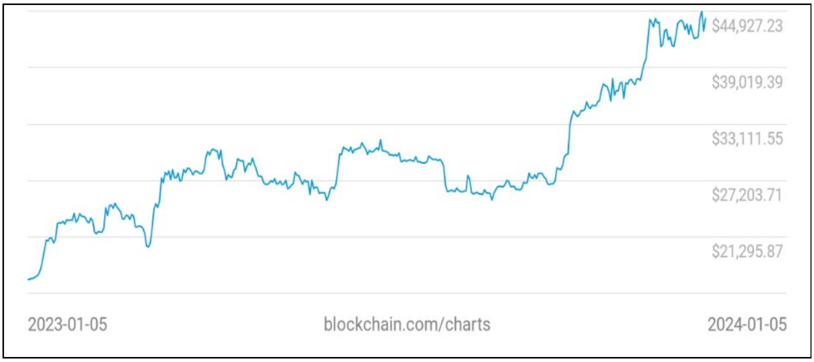

Figure 2. Bitcoin market price

Source: Configured by the author based on the data and the charts options available on the website Blockchain.com

Another element to take into consideration is the numbers of miners. As the number of miners is higher, the mining activity must increase in difficulty, so the likelihood of discovering a valid block decreases. To solve this issue, the miners have to use more powerful hardware in order to achieve the same success rate. However, this solution is directly connected to the cost of energy and leads to the need for hardware/technology with a higher hash rate and a lower energy footprint. To have a complete picture of this complex issue, it is important to also show that the cost of energy is different between countries. According to the latest information published by Eurostat (Electricity price statistics - Statistics Explained (europa.eu)), the lowest fare is found in the Netherlands (0.0595 euro per KWh). The medium in the European Union is 0.2525 euro per KWh.

3. Estimated climate impact of crypto-assets

Referring to the climate impact of crypto-assets, especially Bitcoin as the most traded crypto using Proof of Work protocols, the opinions are divided. For example, Bitcoin Mining Council is arguing that global mining of Bitcoin has a sustainable energy mix. Figure 6 presents an overview of the estimate. The first bar represents values for data from the miners, as annualised primary energy use, while the second bar shows the estimation for the global network power (assumptions and extrapolation of the Bitcoin Mining Council). The rest of the data are country data compiled from official statistical sources on energy consumption for 2021.

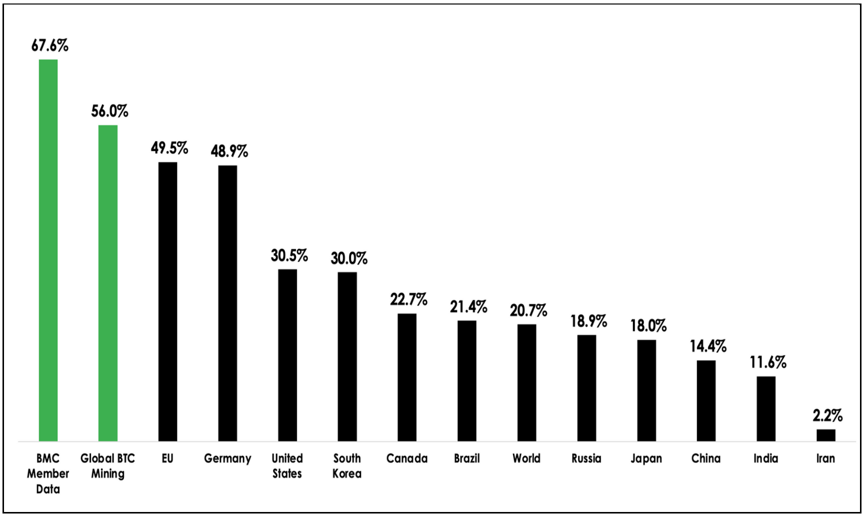

Figure 3. Energy power: Bitcoin Mining vs. Countries consumption (% of KWh)
Source: Data are obtained from the website Bitcoin Mining Council.

According to the data published by Bitcoin Mining Council (https://bitcoinminingcouncil.com), miners are consuming at global level only 0.1% of the world's energy productions and 0.4% from the world's energy wasted. They argue that in the US, 65% of the energy is wasted or lost while being generated and distributed. Meanwhile, 2.8% of this energy is consumed to mine Bitcoin. Regarding the source of energy for mining, they claim that 56% is a sustainable energy mix (the value is calculated for Q2 2021), while the network efficiency is increasing. As technology evolved, the hash rate is composed of more efficient mining tools, resulting in a reduced carbon footprint.

Cambridge Centre for Alternative Finance (CCAF) is calculating a Bitcoin Electricity Consumption Index. Based on the information published by CCAF (https://ccaf.io/cbeci/index), the estimated power demand fluctuated over the years, the highest values being between 2021-2022 (around 15.8 GW). Also, the CCAF is calculating the total Bitcoin electricity consumption and according to their data, the annual consumption for the first quarter of 2023 is 27.16 TWh and the total is estimated at 440.21 terra watt hours. It is worth mentioning that the consumption is increasing every year. For example, 14.44 TWh was consumed in 2017. Köhler & Pizzol (2019), identified geographical distribution and hardware efficiency as the main factors influencing the total footprint for Bitcoin, while other factors were considered to have a minor impact (<1%). Vries, A., Gallersdörfer, U., Klaaßen, L., & Stoll, C (2022), showed that the carbon footprint of Bitcoin can be estimated based on electricity sources used by miners. Previous studies presented different methods for approximating mining locations and, based on one of these approaches, the Cambridge Centre for Alternative Finance regularly generates a map that shows the global distribution of miners, using Internet Protocol (IP) address information collected from four 'mining pools':BTC.com, Poolin, ViaBTC, and Foundry USA.

As the footprint for Bitcoin mining is influenced by the energy price and sources, it is important to observe the main sources of energy and their associated footprint (see Table 1).

Table 1. Electricity sources and life-cycle

Electricity source	Life-cycle greenhouse gas emissions (gCO_2e/kWh)
Coal	1,001
Oil	840
Gas	486
Nuclear[1]	13
Hydro	21
Solar[2]	35.5
Wind[3]	13
Other renewables[4]	32.3

Note: [1]Light-water reactor, [2]Photovoltaic and concentrating solar power, [3]Land-based, [4]Geothermal, biomass and ocean.

Source: The values are collected by the author from the studies performed by the National Renewable Energy Laboratory (2021).

Having in mind the data and the factors influencing the global level of distribution of miners (see the crackdown in China, the internet crisis in Kazakhstan, the clean energy sources from Germany and Ireland, and the lack of data for these countries, in terms of mining), in the most recent years, the academics concentrated their efforts on estimating the carbon footprint for crypto-assets. Köhler & Pizzol (2019), observed that using average emission factors (557.76 gCO2/kWh) and the Bitcoin network's estimated electric load demand (13.39 GW as of August 2021), Bitcoin mining may be responsible for 65.4 megatons of CO2 (MtCO2) per year, being comparable to country-level emissions in Greece (56.6 MtCO2 in 2019), representing 0.19% of global emissions. The estimation can change if Canada induces changes for Bitcoin mining. For example, it should be considered that Black Rock Petroleum Company announced the deployment of up to 1 million Bitcoin mining machines on gas-producing sites in Alberta, while in Quebec, in 2019, the power available for miners was limited to 688 megawatts. Other countries may come with similar approaches as their transition to green and sustainable sources for energy is starting to be implemented and if they adopt policies that follow this direction.

Another element that should be considered when estimating the climate impact of crypto-assets is the use of marginal emission factors, as all the studies presented considered only the average emission factors. As mining activities increase the power demand, thus activating additional electricity generation resources, additional energy sources may appear. The issue is that in some areas, for example, in New

York, stranded fossil assets[4] may be reactivated to sustain Bitcoin mining activity. Alternatively, in Kentucky, the state grants tax reductions in order to attract Bitcoin operations with the objective of saving the coal companies and creating jobs. These actions transcend simple affirmations, being supported by figures. According to Cambridge Bitcoin Electricity Consumption Index, in 2021, the estimated carbon footprint of Kentucky state was 3.3 Mt CO_2. Moreover, Russia represents a jurisdiction where companies that participate in the crypto market attempt to utilise flare gas as a source for Bitcoin, with the scope of gaining revenue. From a climate impact perspective, flare gas generates the same amount of carbon emissions as flaring.

The literature is usually referring to Bitcoin footprint, based on the fact that is the most tradable crypto-asset and also uses proof of work protocol implying mining activities and generating electricity consumption from different sources, not sustainable in the majority of the cases. For authorities and countries, as they are moving towards green and sustainable environment, it is important to also consider the impact of other crypto-assets, such as Ethereum, for example.

Bitcoin is not the only crypto-asset using consensus mechanism and with significant carbon footprint, meaning that the climate impact is not resuming only to Bitcoin but also to other crypto-assets. In response to this major preoccupation and taking into consideration the coming green policies of countries, crypto-assets issuers started to take action. One example is Ethereum, which has announced a set of upgrades to make ether more sustainable. Also, Bitcoin Mining Council (BMC) has announced for Bitcoin, two notable initiatives regarding the Crypto Climate Accord that has the proposed objective to decarbonise the crypto-asset market. A large number of parties have joined this initiative to achieve net zero emissions by 2030. Another important element is related to the fact that renewable energy sources are limited[5] and moving mining activities in this direction may affect the countries' green transition strategies. Countries need time to have fully renewable energy supplies, and adopting policies and strategies to support the transition are crucial in order to avoid using existing renewable energy for commercial reasons, such as for mining activities and providing less renewable energy for other purposes, such as household usage. One option to address the issue without affecting transition to green energy is to promote that type of crypto-assets which are not using PoW protocol and are based on proof-of-stake (PoS). In the case of PoS, the miners must lock up (or 'stake') a certain amount of the underlying crypto-asset as a form of collateral for the security of the network. Therefore, for PoS, computing power is not the element used to validate the transaction, leading to substantially lower energy consumption.

If we look at the entire crypto-assets market, we can observe that crypto-assets using PoS protocols have increased in the last years in terms of market capitalisation, but still the market capitalisation of crypto-assets using PoW remains highest, at around 80% of the total crypto-asset market (according to Crypto-compare.com).

[4] i.e., assets that are no longer generating an economic return.
[5] The share of renewables in global electricity generation was 29% in 2020.

Referring to Bitcoin as the most important and used PoW based crypto-asset, the network argues that PoW is the most secure and decentralised consensus mechanism, so it is difficult to predict if bitcoin's stakeholders will start the transition to PoS in the near future. The European Central Bank published a paper estimating that PoS blockchain technology can dramatically reduce energy consumption, while ensuring the same functionality as PoW and security requirements. The decision of Ethereum to move from PoW to PoS is expected to have a significant impact on energy consumption, reducing consumption by 99.95% while ensuring the same functionality.

4. Data and methodology of the study

This section presents the methodology applied with the scope to assess the carbon intensity of Bitcoin and then try to estimate the optimal mean–variance efficient weight of Bitcoin. Our study comprises four parts. First, we calculated the carbon footprint for Bitcoin as the main crypto-asset using the PoW protocol. As a general remark, we understand that carbon footprint relates to a company's carbon performance and the data refers to the extent to which the business activities are based on carbon usage for a defined scope (Hoffmann and Busch, 2008). Therefore, we calculate the carbon footprint as a ratio that divides absolute carbon emissions by a 'related business metric' (Hoffmann and Busch, 2008). Referring to the business metric, there are possible solutions, including unit of production, sales/revenue, and market capitalisation (Hoffmann and Busch, 2008).

We used nonlinear autoregressive distributed lag (NARDL) model, as it presents the advantage to account for both short- and long-term asymmetries, by modelling asymmetric cointegration (Mensi et al., 2016; Demir et al., 2021). NARDL can analyse the presence of any asymmetry of non-stationary variables, being suitable as most price series are usually non-stationary. Using the NARDL model, we solve the issues of multicollinearity by selecting the appropriate lag order for the included variables (Shin et al. (2014)). Additionally, we were able to measure the impact of each independent variable on the dependent variable. NARDL is suitable for analysing the long-run and short-run relationships between variables in economic and financial contexts, due to the fact that relationships may be more complex and exhibit non-linear patterns. The NARDL model allows for capturing such non-linearity's by incorporating non-linear functions of the variables into the model.

The general structure of a NARDL model might look like this:

$$\gamma_t = \propto + \beta_1\gamma_{t-1} + \beta_2\gamma_{t-2} + \cdots \beta_p\gamma_{t-p} + \gamma_1 X_{t-1} + \gamma_2 X_{t-2} + \cdots + \gamma_q X_{t-q} + f(Zt) + \in_t$$

- γ_t - dependent variable;
- X_t - independent variables;
- Z_t - additional variables that may have a non-linear effect on the dependent variable;
- ϵ_t - error term.

The non-linear relationship between the additional variables and the dependent variable is captured by the function $f(Z_t)$. The non-linear components allow for more flexibility in representing complex relationships in economic and financial data. In our study we included the following variables: climate policy uncertainty (CPU), Bitcoin prices (BTC), and the global price of energy index (GPEI). We use the monthly time-series data of BTC, CPU and GPEI for the last 10 years, respectively, for 2013–2023. The values for CPU were collected from www.economicpolicyuncertainty.com, the GPEI data was extracted from https://fred.stlouisfed.org and Bitcoin data from www.Cryptocompare.com. Our study is referring only to Bitcoin for the time being as this is the leading crypto-asset with the biggest market capitalisation and the highest energy consumption.

We used NARDL to decompose the CPU and GPEI into positive and negative partial sums.

$$CPU_t^+ = \sum_{i=1}^{t} \Delta CPU_i^+ = \sum_{i=1}^{t} \max(\Delta CPU_1, 0) \quad (1)$$

$$CPU_t^- = \sum_{i=1}^{t} \Delta CPU_i^- = \sum_{i=1}^{t} \min(\Delta CPU_1, 0) \quad (2)$$

$$GPEI_t^+ = \sum_{i=1}^{t} \Delta GPEI_i^+ = \sum_{i=1}^{t} \max(\Delta GPEI_1, 0) \quad (3)$$

$$GPEI_t^- = \sum_{i=1}^{t} \Delta GPEI_i^- = \sum_{i=1}^{t} \min(\Delta GPEI_1, 0) \quad (4)$$

The results (see Tabel 2 below) regarding the descriptive statistics show that the variables included in the study are first-differenced stationary at a 1% significance level.

Table 2. Descriptive statistics

	BTC	CPU	GPEI
Mean	7.8634	4.6570	4.9302
Std. Deviation	1.7104	0.5921	0.3217
Skewness	0.0698	-0.1194	0.0004
Kurtosis	1.7532	2.6032	2.7809
Jarque-Bera	6.7808	0.9017*	0.0337*

Note: * indicates significance at 1% level.

Source: Data is calculated by the author.

We tested the linearity of the variables by applying Brock–Dechert–Scheinkma (BDS) test of Brock et al. (1996), confirming that the variables included in the study are nonlinear (see Table 3).

Table 3. BDS test results

m	BTC	CPU	GEPI
2	0.169105*	0.192290*	0.023103*
3	0.288272*	0.323998*	0.034755*
4	0.369104*	0.414113*	0.042169*
5	0.423254*	0.475130*	0.045248*
6	0.458289*	0.516072*	0.042847*

Note: * indicates significance at 1% level.
Source: Data is calculated by the author - as result of applying BDS test.

Table 4 presens the NARDL estimation results. We find that the statistics are significant at 1% and 10% levels for the FPSS- and tBDM, confirming that CPU and GPEI are moving together, leading to a linear combination. We also observe that, in the short-term, the CPU's increase has a higher negative impact on Bitcoin prices. This can be understood in the sense that an increase in climate policy uncertainty has the potential to negatively affect the Bitcoin prices, justified by the impact on cost of energy and volatility in the energy markets.

Table 4. NARDL estimation results

CPU's effect on BTC	GPEI's effects on BTC
Short-term estimates	
0.1337***	0.0021
0.0153*	0.3146
Long-term estimates	
0.2001*	0.0572*
0.1898*	0.1920*
Bounds tests	
7.3136* (FPSS)	5.9238*
- 5.5432* (tBDM)	- 3.0921***

Notes: Superscripts "*", "**", and "***" indicate significance at 1%, 5%, and 10% levels, respectively.
Source: Data is calculated by the author - as result of applying NARDL model.

Increasing CPU showed evidence that will affect the valuation of Bitcoin market, and we can assume that this finding is also visible in relation to all crypto-assets using PoW protocols, leading to a fall for crypto and consequently to a decrease of their prices. Our results support the data and information presented in our paper: Bitcoin mining activities require a significant amount of energy consumption with a potential negative impact on the climate. The CPU directly affects the profitability of mining activities, and this is leading to a decrease in the overall hash rate of the Bitcoin network, with direct and sever implications on the security and reliability of the network. Meanwhile, our result showed that GPEI's decrease has a positive impact on Bitcoin prices, respectively, which would make Bitcoin mining and operation profitable, as energy cost is one of the most significant costs for mining activities. In addition, we performed a Granger test in order to determine if one-time series has a causal effect on another time series, taking into consideration the nonlinear relationships between the variables. The Granger test is a relevant tool for observing hidden causal relationships that may not be observed using linear models.

Table 5. Granger test results

Series	CPU→BTC	BTC→CPU	Series	GPEI→BTC	BTC→GPEI
CPU^{+}	1.640**	1.527***	**$GPEI^{+}$**	1.873**	0.925
CPU^{-}	2.103**	2.27**	**$GPEI^{-}$**	1.582**	0.655

Notes: Superscripts “*", “**", and “***" indicate significance at 1%, 5%, and 10% levels, respectively.

Source: Data is calculated by the author - as result of applying Granger casual test.

The Granger test (results are presented in Table 5) shows a significant bidirectional nonlinear granger causality between the increase and decrease in CPU and BTC. This can be explained by the perception of investors about energy consumption, which is also influencing changes in Bitcoin prices. Due to the fact that Bitcoin is using PoW protocols, any climate concerns could raise pressure on the investors and consumers and decide to move towards more environmentally-friendly crypto-assets. In the end, this would affect Bitcoin's market share. In addition, climate policy and strategies may lead to innovation and new developments for more energy-efficient Bitcoin mining technologies.

Regarding the GPEI, we observed~~i~~ an increase and decrease in the GPEI unidirectional granger cause BTC. Mining activities involve a significant amount of energy consumption, especially due to the computing power needed to solve complex mathematical equations to verify transactions and add new blocks to the blockchain. This means that the energy cost is a significant element in relation to the profitability of Bitcoin mining activities, in the sense that if the energy prices are high, mining BTC becomes more expensive, reducing the profitability of mining and potentially decreasing the interest for this activity, and thus reducing the amount of Bitcoin being produced.

5. Conclusions

Our study extends prior academic papers by using more recent data related to BTC and relatively advanced techniques known as NARDL. The academic literature presents different results regarding the carbon footprint related to mining activities, especially calculated in relation to Bitcoin (Christian Stoll, Lena Klaaßen, Ulrich Gallersdorfer, 2019). Additionally, authorities and countries have their strategies and policies regarding green transitions, which will have a significant impact on crypto-assets market and their valuation. Moreover, the events related to the usage of renewable electricity sources for mining activities, in the sense of decreasing in conjunction with other events related to the crackdown in China, should be understood by the stakeholders in the crypto industry as a need to take action and to accelerate the efforts to decarbonise the industry. As presented in this paper, some decisions, such as the one related to the Crypto Climate Accord, have already been taken in this direction. This partnership is a commitment from the crypto industry to increase the use of renewable electricity to 100% by 2030. The Accord is the first step, and it has to be complemented with other measures, for example, with some compliance mechanisms in order to ensure that the objective is achieved.

However, if we consider that the industry will succeed in reducing the carbon footprint of mining activities and increase the use of green energy, other elements have to be highlighted. One of these is related to the action taken by the Swedish Financial Supervisory Authority and Environmental Protection Agency banning crypto mining, as they consider that the use of renewable electricity for mining could delay the energy transition of essential activities and services in line with country strategies. In addition, it seems that changing the consensus mechanisms is not a solution on short term due to its complexity, but rather encouraging the use of other crypto-assets using more energy-efficient protocols. The assumption can be supported by the case of Ethereum, that decided to switch from PoW to PoS since its inception 6 years ago and they still did not finish the process completely that will allow for the migrations towards more energy-efficient sources.

For the crypto market to succeed in the financial ecosystem, all parties involved - users, investors, stakeholders - must take radical decisions and change the actual way of performing activities related to Bitcoin (mining, rewarding mechanisms, applying incentives for user and stakeholders to support this transition). If this transition succeeds, the crypto market may become an example for other industries facing similar challenges. While expecting the crypto market's reaction and actions, the authorities are also considering some policies and actions in order to prevent increasing financial sector exposures to crypto-assets with a significant carbon footprint and climate transition risk. Here we are not referring only to governments, but also to prudential regulators that have strategic roles to play with respect to the financial institutions they supervise. Each country will have to assess in a very adequate manner if the carbon footprint of crypto-assets affects the fulfilment of their goals in relation to their green transition strategies. Other stakeholders will have to consider and evaluate the decision of engaging or investing in some crypto-assets and make sure such actions are in line with their green objectives. Financial institutions will be the first to incorporate the climate-related financial risks of crypto-assets into their climate strategy, as this is already an obligation for the financial system and promoting green finance is a priority for the European authorities. Prudential regulators have sufficient instruments to ensure the implementation of these objectives, for example, they may decide to define capital requirements or to apply sanctions in order to correct the conduct of the institutions. Still, this measure has some limits considering the fact that crypto-assets are not significant components in the portfolios of the banks, or in some markets not at all are included or permitted by the regulators (see the case of Romania).

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