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The control of greenhouse gas emissions generated by the use of cryptocurrencies

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Abstract: This research outlines how the use of cryptocurrencies like blockchain can be detrimental to the environment, primarily due to the emission of greenhouse gases. The research is justified in light of the current relevance of the topic, as carbon emission control is a global and governmental concern for the preservation of the environment for future generations. The investigation began by addressing the issue of greenhouse gas emissions due to the use of cryptocurrencies such as bitcoin through blockchain. Subsequently, the importance of controlling greenhouse gas emissions and the associated indices due to the use of cryptocurrencies were discussed. Following that, the policies for controlling greenhouse gas emissions in Brazil were examined. Through theoretical-literature review, documentary research, and deductive methods, it was determined that the use of clean energy sources is necessary for the maintenance of this technology to reduce the environmental impacts it currently poses. The study highlights the need for using clean energy or alternative methods in the utilization of cryptocurrencies to avoid the high release of greenhouse gases as observed in current practices.

Key words: emission of gases, greenhouse effect, cryptocurrencies, blockchain, new technologies

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INTRODUCTION

Bitcoin is a decentralized cryptocurrency created in 2009 by an individual or group of individuals under the pseudonym Satoshi Nakamoto (2008). It operates as a peer-to-peer electronic payment system that enables money transfers without the need for an intermediary, such as a bank. Nakamoto (2008) compared the creation of new coins in this way with gold mining (hence the term Bitcoin mining), and noted that "in our case, it's CPU time and electricity that is expended".

There is a growing interest among consumers in financial transactions involving cryptocurrencies, as evidenced by the high search volume for terms related to Bitcoin, blockchain, and cryptocurrencies on Google Trends. Searches for "Bitcoin" appear to be more intense than those for "cryptocurrency" and "blockchain", especially in Western economies (Polemis and Tsionas 2023, 3). Bitcoin has increasingly become a part of financial transactions, with a market capitalization in the billions of dollars and a growing number of cryptocurrencies in circulation. However, the blockchain validation process consumes a significant amount of electricity, resulting in substantial carbon dioxide (CO2) emissions, raising concerns about its environmental impact.

The security of the Bitcoin network is ensured through encryption, a coding technique that protects transactions and user identities. Each transaction is recorded in a public ledger known as the blockchain, which is an immutable digital ledger allowing verification of all transactions.

Blockchain is a distributed ledger technology that enables the creation of a secure, decentralized database shared among multiple parties without the need for a centralized intermediary for transaction validation. According to Tapscott and Tapscott (2016), blockchain is a digital ledger composed of interconnected transaction blocks, forming an immutable chain of records.

The functioning of blockchain is based on cryptography, ensuring the security and privacy of transactions. Each transaction is validated by a network of nodes using consensus algorithms to verify information authenticity. According to Antonopoulos (2014), the decentralization of blockchain ensures system integrity, as there is no single point of failure, making it resistant to malicious attacks.

Blockchain also emerged in 2009 with the creation of Bitcoin, the first decentralized cryptocurrency using blockchain as a transaction record. A Blockchain is a list of encrypted digital record or transaction, called a

block. Each block is then "chained" to the next block, in a linear, chronological order, using a cryptographic signature. The blocks contain a copy of the last transactions since the last block was added (Bogart and Rice 2015). Thus, the shared block, or ledger, is linked to all participants who use their computers in a network to validate or confirm transactions, removing the need for a third-party (Christidis and Devetsikiotis 2016; Porru et al. 2017). The price of Bitcoin is determined by market supply and demand and can be extremely volatile. It is also affected by macroeconomic, regulatory, and security events.

While Bitcoin has been praised for its ability to provide a fairer and more inclusive financial system, it also faces criticism for its negative environmental impacts. Bitcoin mining consumes a significant amount of energy, mainly due to the use of specialized hardware to solve complex mathematical problems necessary for transaction validation and adding new blocks to the blockchain. This mining process is known to be highly energy-intensive and can have significant environmental impacts.

Concerns about greenhouse gases are central to the debate on environmental preservation and the mitigation of global climate change. Greenhouse gases, such as carbon dioxide, methane, and nitrous oxide, trap part of the solar radiation in the Earth's atmosphere, contributing to the increase in the planet's average temperature. This temperature rise can trigger a series of negative impacts, such as polar ice cap melting, sea level rise, extreme weather events, and a reduction in the availability of drinking water. In this context, it becomes essential to seek alternatives to reduce greenhouse gas emissions and mitigate the impacts of climate change, aiming to ensure a sustainable future for the next generations.

The research issue is the environmental repercussion of blockchain usage. The problem is: is such currency sustainable? The central objective is to demonstrate the environmental repercussions of blockchain usage. Specific objectives include exploring the environmental impacts of using bitcoin and how it affects greenhouse gas emissions. The research was conducted through a systematic and deductive review method. Regarding the technical procedures for collecting the data that guided the research, a bibliographic survey was used, with focus on doctrinaire, normative, and jurisprudential readings related to the issue, since they provided the theoretical basis for the preparation of the paper and discovery of other concepts that allowed the issuance of a conclusive opinion after the end of the research.

ENERGY CONSUMPTION THROUGH BITCOIN

Despite being a technology considered innovative, due to the freedom it offers in financial transactions and investments, Bitcoin and other cryptocurrencies have serious environmental implications. Bitcoin, the highest representative of cryptoassets based on blockchain technology, is an "energy-hungry" currency, whose sources are not necessarily the cleanest and, therefore, represents a real barrier to efforts to combat climate change. Blockchain technology relies on the solution of complex cryptographic problems to validate transactions or records. To solve these problems, thousands of computer nodes attached to the network participate, giving rise to a competition to validate a new transaction and obtain the reward, this is the so-called "cryptocurrency mining" (Artiga and López 2021, 3).

The mining process of bitcoin requires enormous amounts of electricity and this results in the release of large amounts of CO2 into the atmosphere. The year 2017 alone, recorded approximately 69 million metric tons of CO2 (Carbon dioxide) emission as a result of bitcoin mining. One blockchain mining transaction can consume as much energy as an entire household requires in a week, not to mention about 300,000 transactions carried out on a daily basis. That high amount of energy demand is more often met by fossil fuel energy sources, which end up polluting both air and water, as well as generate greenhouse gas emissions that cause climate change (Egiyi and Ofoegbu 2020, 16).

The "Bitcoin Energy Consumption Index" portal highlights that the energy consumption of the Bitcoin network is a significant problem that needs to be addressed if the cryptocurrency intends to become a viable alternative to traditional money. The article introduces the Bitcoin Energy Consumption Index as an essential tool for monitoring the energy consumption of the Bitcoin network and assessing its environmental impact. The tool is regularly updated, providing estimates of the Bitcoin network's energy consumption.

The authors suggest that solutions such as the use of renewable energy sources and the development of more efficient mining algorithms can help reduce the energy consumption of the Bitcoin network. However, they emphasize that these solutions require collaboration from all network participants and are not easy to implement.

In April 2021, the Bitcoin Energy Consumption Index indicated that Bitcoin mining consumed more energy than the entire country of Argentina, totaling around 121.36 TWh per year. The index also suggests that the carbon footprint of the Bitcoin network is comparable to that of New Zealand, with approximately 57.22 MtCO2 per year. Additionally, Bitcoin mining generates a significant amount of electronic waste, as mining equipment has a short lifespan and is frequently replaced. Bitcoin mining is also highly concentrated, with the majority occurring in a few countries, leading to imbalances in global economic power distribution. Thus, Bitcoin mining presents significant challenges regarding environmental sustainability and economic equity.

In summary, the article emphasizes the importance of monitoring the energy consumption of the Bitcoin network and developing solutions to make the technology more sustainable. The Bitcoin Energy Consumption Index plays a crucial role in raising awareness among users about the environmental impact of Bitcoin mining and promoting the adoption of more sustainable practices.

Investigating the carbon emission flows of Bitcoin's blockchain operation in China using a simulation-based Bitcoin blockchain carbon emission model, the article "Policy Assessments for Carbon Emission Flows and Sustainability of Bitcoin's Blockchain Operation in Chin" from the Nature journal states that without policy interventions, the annual energy consumption of Bitcoin's blockchain in China is projected to peak in 2024 at 296.59 TWh, generating 130.50 million metric tons of corresponding carbon emissions. Internationally, this emission would exceed the total annual greenhouse gas emissions of the Czech Republic and Qatar. Nationally, it would rank among the top ten out of 182 cities and 42 industrial sectors in China (Jiang 2021, 1).

The paper discusses how Bitcoin mining, using the Proof-of-Work (PoW) algorithm, contributes to increased energy consumption and significant carbon emissions. Given China's position as one of the world's largest energy consumers, Bitcoin mining in the country has substantial impacts on emission reduction targets. The study proposes three policy scenarios to address the issue: the "Benchmark" scenario considers the current situation with minimal policy intervention, while the "Market Access" and "Site Regulation" scenarios involve adjustments to mining practices for energy savings and emissions reduction. The "Carbon Tax" scenario increases carbon taxes to penalize high-emission behaviors. The study highlights the importance of addressing this issue effectively to avoid negative impacts on environmental sustainability and the country's emission reduction goals.

China's situation is further complicated by its participation in the Paris Agreement, aiming to limit the increase in the global average temperature. Under the Paris Agreement, China is committed to reducing carbon emissions by 60% by 2030 (based on 2005 data). However, according to Jiang et al., the carbon emission pattern of the Bitcoin blockchain poses a potential barrier to China's emission reduction goal. The annualized emission peak of the Bitcoin mining industry would make it the tenth-largest emitting sector out of 42 major Chinese industrial sectors. It would be responsible for approximately 5.41% of electricity generation emissions in China. The carbon emission peak per GDP of the Bitcoin industry is estimated to be 10.77 kg per USD. Additionally, in the current national economy and China's carbon emission accounting, the Bitcoin blockchain operation is not listed as an independent department for carbon emissions and productivity calculation. This adds difficulty for policymakers to monitor the industry's actual behavior and design well-targeted policies. In fact, the energy consumption per Bitcoin network transaction is higher than several conventional financial transaction channels. To address this issue, policymakers are suggested to create separate accounts for the Bitcoin industry to better manage and control its carbon emission behavior in China.

It is noteworthy that the relationship between resource transformation into electricity is a clear demand in pioneer countries in the cryptocurrency mining scene. However, the greater the demand, the more negative impacts there will be in the face of unbridled supply. Decentralization initially prevents greater oversight of the impacts arising from this practice, but one should not turn a blind eye to the studies already published with their respective confirmations (Divino and Antunes 2021).

By the way, proof-of-work cryptocurrency mining consumes massive amounts of electricity. Bitcoin's global electricity consumption alone increased more than threefold between the beginning of 2019 and May 2021 (Huang et al. 2021). This concern prompted Elon Musk, CEO of Tesla, to express opposition to Bitcoin in May 2021. He announced that the company would no longer accept Bitcoin as a form of payment due to the cryptocurrency miners' excessive use of energy. In a tweet, he stated: "We are concerned about the rapid increasing use of fossil fuels for Bitcoin mining and transactions, especially coal, which has the

worst emissions of any fuel". Later, in July of the same year, Musk changed his stance and declared that Tesla would again accept Bitcoin as payment if there was proof that more than 50% of the energy used by miners came from renewable sources. In a conference, he stated: "If Bitcoin mining is done with more than 50% clean energy, then we will consider again the possibility of Tesla accepting bitcoin for transactions" (G1 2021).

In another analysis of the environmental impacts of Bitcoin, similar results are found. The article "Bitcoin and beyond: A technical survey on decentralized digital currencies" by Tschorsch and Scheuermann (2016), published in the IEEE Communications Surveys & Tutorials journal, discusses the environmental implications of the Bitcoin system and other decentralized digital currencies.

The authors state that Bitcoin mining is an energy-intensive process, leading to a significant carbon footprint. According to the study, in May 2015, the Bitcoin network consumed about 300 megawatts of energy, equivalent to the energy consumption of 300,000 homes in the United States. In 2019, this number increased to about 7.8 gigawatts, equivalent to the annual energy consumption of a country like Austria. Additionally, the study highlights the issue of improper disposal of mining hardware, which can lead to environmental contamination. The authors mention that mining hardware disposal may include hazardous materials such as lead and mercury, which can pollute the environment if not disposed of properly.

The authors also discuss the possibility of alternative solutions to mitigate the environmental impacts of Bitcoin, such as using renewable energy sources to power mining. They claim that "Bitcoin mining can benefit greatly from the use of renewable energy sources, such as hydro, wind, and solar power", which could significantly reduce the system's carbon footprint.

In summary, the research emphasizes concern about the carbon footprint and improper disposal of mining hardware in the Bitcoin system and decentralized digital currencies, emphasizing the importance of alternative solutions based on renewable energy sources. Thus, it is evident that the two scientific articles discussed in this research and the repercussions in the financial market of pollution and greenhouse gas generation by Bitcoin share the same concern: it is necessary to find alternative solutions based on renewable energy sources to avoid an increase in pollution by this technology.

CARBON EMISSION CONTROL

Greenhouse gases are emitted as a result of human activities. Carbon dioxide is the first and most prominent in the list of greenhouse gasses. Excess burning of fossil fuels such as coal and petroleum is the major causes of carbon production. Furthermore, deforestation or removal of trees for the purpose of acquiring lands for agricultural purposes and industrial activities also contribute to the large quantity of carbon dioxide in the atmosphere. The manufacture of cement also contributes to increased level of carbon dioxide in the atmosphere which happens when calcium carbonate is heated to produce lime and carbon dioxide. Methane, commonly known as natural gas, is the second greenhouse gas found in the atmosphere. It is produced from agricultural activities like paddy rice farming and use of farmyard manure. It is also produced as a result of improper waste management. Nitrous oxides are created mainly by fertilizers. Moreover, several industrial processes like refrigeration lead to the production of gases such as chlorofluorocarbons (CFCs) (Egiyi and Ofoegbu 2020, 17).

Brazil, a signatory of the United Nations Framework Convention on Climate Change (UNFCCC), has committed to reducing greenhouse gas (GHG) emissions by 37% by 2025 and 43% by 2030, compared to 2005 levels. This move towards carbon emission control is crucial for environmental preservation for both current and future generations. The engagement of various nations in international agreements aiming to reduce global climate change has been the primary driving force behind this movement.

In Germany, for instance, in the case "Neubauer et al. versus Germany", the German Constitutional Court ruled that the government has a "constitutional obligation concerning climate change, which includes the equitable distribution of what remains of the permitted emissions in the carbon budget over time and generations, and eventually achieving climate neutrality" (Kotzé 2021, 1.437).

There are two main forms of carbon emission control: regulated and voluntary markets. The regulation of carbon emissions was established by the UNFCCC during the United Nations Conference on Environment and Development (ECO-92) held in Rio de Janeiro. Controlling greenhouse gas emissions is a crucial issue for mitigating global climate change, and Bitcoin mining and transactions have been identified as activities with significant greenhouse gas emission potential.

Internationally, a carbon credit is defined as one ton of carbon dioxide (CO2), a standard unit enabling the quantification and trading of greenhouse gas emission reductions. However, it's essential to note that other substances, such as methane, also contribute to the greenhouse effect. To address the emission of these additional gases, the concept of "carbon equivalente" emerges, allowing the measurement of the total amount of greenhouse gases released by a specific activity or process.

The international carbon credit market offers an innovative approach to combating climate change. Countries with unused emission limits have the opportunity to sell surplus credits to other nations seeking to meet their emission reduction goals. This compensation system provides economic incentives for nations to reduce emissions, encouraging the adoption of more sustainable and efficient practices.

In addition to the market between national and regional governments, a voluntary emissions reduction market has emerged, where companies and individuals interested in demonstrating environmental commitment can purchase carbon credits. Even without being tied to any national or international standards, these entities choose to participate in the voluntary market to strengthen their image and socio-environmental responsibility.

Opportunities to obtain carbon credits in the voluntary market are diverse. Sustainable projects in areas such as sustainable agriculture, biofuel production, energy efficiency, conservation and reforestation, renewable energy, and waste reuse are examples of initiatives that can generate carbon credits. The implementation of these projects is assessed by international standards to ensure the credibility and legitimacy of the credits.

In Brazil, there is a growing effort to control and reduce greenhouse gas emissions. The country has developed procedures for the elaboration of Sectoral Plans for Mitigating Climate Change and established the National System for Greenhouse Gas Emission Reduction. These initiatives aim to coordinate efforts and establish strategies to achieve national emission reduction goals, aligning with commitments made in the Paris Agreement.

Furthermore, Brazil is also working to regulate the Brazilian Emission Reduction Market (MBRE) through Bill No. 412 of 2022. This regulation aims to provide a legal and transparent framework for carbon credit trading in the country, promoting the effectiveness of emission reduction actions.

This concern with controlling greenhouse gas emissions reflects Brazil's commitment to combating climate change and contributing to global sustainability efforts. The implementation of policies and participation in carbon credit markets represents significant steps towards a greener and climate-resilient economy. With the collaboration of governments, companies, and individuals, it is possible to promote a more sustainable future for future generations.

However, Bitcoin mining also needs to be a concern to achieve internationally agreed-upon greenhouse gas emission levels by Brazil. According to a study conducted by Kolluru et al. (2021), the Bitcoin mining process can generate significant greenhouse gas emissions, mainly due to the high electricity consumption required for solving the complex mathematical calculations that validate Bitcoin transactions. According to the authors, in 2020, Bitcoin mining was responsible for about 37 megatons of CO2 emissions, comparable to the greenhouse gas emissions of cities like Las Vegas or Hamburg.

Additionally, Bitcoin transactions can also generate significant greenhouse gas emissions, according to a study by De Vries (2018). The authors point out that, due to the decentralized nature of the Bitcoin network, transactions may require multiple confirmations, leading to higher electricity consumption and, consequently, higher greenhouse gas emissions.

In this scenario, initiatives have emerged to try to reduce greenhouse gas emissions associated with Bitcoin. One such initiative is the "Bitcoin Clean Energy Initiative", led by MicroStrategy, which aims to encourage Bitcoin mining with renewable energy, such as solar and hydropower.

The "Bitcoin Clean Energy Initiative" is an initiative led by the technology company MicroStrategy, which seeks to encourage Bitcoin mining with renewable energy. The company has launched a financial incentive program for Bitcoin miners who can prove they are using clean energy sources, such as solar and hydropower, in their operations.

The goal of the program is to encourage the transition of Bitcoin mining from fossil energy sources to renewable energy sources, aiming to reduce the greenhouse gas emissions associated with Bitcoin mining. The initiative also aims to make Bitcoin mining more sustainable and environmentally responsible.

Furthermore, MicroStrategy has also announced plans to invest in renewable energy projects to support its own Bitcoin mining and promote the adoption of clean energy sources in the Bitcoin network overall. The "Bitcoin Clean Energy Initiative" is an example of how companies and organizations can contribute to the environmental sustainability of the cryptocurrency sector and minimize the environmental impact of Bitcoin mining.

In summary, greenhouse gas control is a fundamental issue for environmental preservation, and Bitcoin mining and transactions are activities that need to be carefully assessed and managed to minimize their environmental impact.

CONCLUSION

The technological advancement of Bitcoin and cryptocurrencies, in general, has ushered in a new financial paradigm, offering opportunities for peer-to-peer transactions without traditional intermediaries. However, this technological progress has also brought significant challenges to environmental sustainability, with Bitcoin mining's energy consumption and greenhouse gas emissions becoming topics of growing concern.

The intensive energy consumption is an intrinsic aspect of Bitcoin's blockchain operation, which employs the Proof-of-Work (PoW) consensus algorithm. This algorithm is crucial for ensuring the security and integrity of transactions on the Bitcoin network but also demands substantial amounts of electricity. With the continuous growth of the cryptocurrency market and mining expansion, the energy consumption associated with Bitcoin has substantially increased, raising questions about its environmental sustainability.

Studies show that Bitcoin mining and blockchain validation are responsible for an annual energy consumption rivaling that of entire countries. This directly impacts greenhouse gas emissions, with millions of tons of CO2 being released annually by the Bitcoin blockchain operation. This environmental impact is a cause for concern, especially in light of global efforts to mitigate climate change and reduce carbon footprints.

While governments and international organizations seek regulatory mechanisms to address carbon emissions and promote the transition to a greener economy, the cryptocurrency industry also faces the challenge of becoming more sustainable. Initiatives like the "Bitcoin Clean Energy Initiative" are positive steps in this direction, encouraging the adoption of renewable energy sources in Bitcoin mining. However, there is still much to be done to effectively mitigate the environmental impact of Bitcoin and ensure the sustainability of this emerging technology.

Moreover, Brazil, as a signatory to the Paris Agreement and committed to reducing greenhouse gas emissions, has implemented policies and strategies to control its emissions. Through Sectoral Plans for Mitigating Climate Change and the National System for Greenhouse Gas Emission Reduction, the country seeks to coordinate efforts to achieve its emission reduction goals. The regulation of the Brazilian Emission Reduction Market (MBRE) is also a significant step to promote the effectiveness of emission reduction actions in the country.

Societies are moving towards a context of severe impacts from extreme weather events and a dramatically changing climate, due to the lack of action by States to achieve mitigation efforts. Besides, it is worrisome that according to the warnings of science, we are reaching limit conditions to achieve adaptation by 2030, which is the year that the Intergovernmental Panel on Climate Change (IPCC) has established as a turning point for climate change to become irreversible (Artiga and López 2021, 8).

Awareness of the environmental impacts of Bitcoin mining and cryptocurrencies is essential for guiding sustainable policies and practices in the sector. Scientific research and the study of carbon emission flows from the operation of the Bitcoin blockchain provide valuable insights to develop effective solutions. Transitioning to clean energy sources and seeking more efficient consensus algorithms can be crucial to reducing Bitcoin mining's energy consumption and carbon emissions.

In the places where Bitcoin mining has arrived, it has provoked an unprecedented waste of energy, having as a fundamental premise the search for cheap, free and continuous energy to keep the blockchain, the technology that gives life to Bitcoin, working. This sickly competition to create new blockchains is a perverse game that wastes energy, while millions of people are denied their right to energy as a global common good (Artiga and López 2021, 8).

Therefore, it is fundamental for governments, the cryptocurrency industry, and society as a whole to collaborate in finding solutions that balance growth and technological innovation with environmental protection. Environmental sustainability should not be an option but an urgent necessity to ensure that future generations can enjoy a healthy and resilient planet.

It is important to emphasize that the issue of energy consumption and associated emissions with Bitcoin is not limited to mining alone. Bitcoin transactions also contribute to energy consumption, especially due to the decentralized confirmation process, which may require multiple confirmations to ensure transaction security. Hence, innovative solutions focusing on energy efficiency throughout the Bitcoin ecosystem are necessary.

Addressing the environmental challenges associated with Bitcoin is a shared liability, and only through collective and collaborative efforts can we create a greener, sustainable, and fairer future for all. In this regard, it is crucial for governments, businesses, organizations, and individuals to take responsibility and proactively act to mitigate the environmental impacts of cryptocurrencies and promote a more sustainable and environmentally conscious economy.

Awareness of the environmental impact of Bitcoin and other cryptocurrencies is crucial to encourage the search for solutions that balance technological innovation with socio-environmental liability.

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