Uluslararası İktisadi ve İdari İncelemeler Dergisi
International Journal of Economic and Administrative Studies
https://dergipark.org.tr/tr/pub/ulikidince

UİİİD-IJEAS, 2024 (44) ISSN 1307-9832

ANALYSIS OF THE IMPACT OF CRYPTO TRADING ON CARBON EMISSIONS USING PATH ANALYSIS[1]

Suzan OĞUZ[2]

Abstract

In parallel with the growing interest in cryptocurrencies, the relationship between crypto trading and CO2 is critical to drive financial markets and environmental sustainability efforts. The aim of this study is to analyse the impact of crypto trading on carbon emissions (CO2) through the mediating roles of international trade and energy use. Within the scope of the study, path analysis was carried out using the 2007-2021 period data of the top 20 countries with high crypto trade volume. A model proposal was presented to examine the relationships between the variables used in the study and the necessary analyses were carried out. The results of the analysis show that crypto trade volume has a positive and significant effect on carbon emissions. It is also concluded that international trade and energy use mediate the relationship between crypto trade and carbon emissions. It is seen that crypto mining activities and cryptocurrencies lead to an increase in energy use and environmental impacts. At this point, it is important for countries to switch to renewable energy sources and to regularly report and monitor the impact of cryptocurrency mining activities on carbon emissions.

Keywords: *Crypto Trading, Carbon Emissions, International Trade, Energy Use, Path Analysis*
JEL Classification: *C32, F18, Q56*

KRİPTO TİCARETİNİN KARBON EMİSYONLARI ÜZERİNDEKİ ETKİSİNİN YOL ANALİZİ İLE İNCELENMESİ

Öz

Kripto para birimlerine olan ilginin artmasına paralel olarak kripto ticareti ve CO2 arasındaki ilişki, finansal piyasaları ve çevresel sürdürülebilirlik çabalarını yönlendirmek için kritik bir öneme sahiptir. Bu çalışmanın amacı, kripto ticaretinin karbon emisyonları (CO2) üzerindeki etkisini uluslararası ticaret ve enerji kullanımı aracılık rolleriyle analiz etmektir. Çalışma kapsamında yüksek kripto ticaret hacmine sahip ilk 20 ülkenin 2007-2021 dönem verilerini kullanarak yol analizi gerçekleştirmiştir. Çalışmada kullanılan değişkenler arasındaki ilişkileri incelemek için bir model önerisi sunulmuş ve gerekli analizler gerçekleştirilmiştir. Analiz sonuçları, kripto ticaret hacminin karbon emisyonları üzerinde pozitif ve anlamlı bir etkiye sahip olduğunu göstermektedir. Ayrıca uluslararası ticaretin ve enerji kullanımının kripto ticareti ve karbon emisyonları arasındaki ilişkide aracılık ettiği sonucuna ulaşılmıştır. Kripto madencilik faaliyetlerinin ve kripto para birimlerinin, enerji kullanımı ve çevresel etkilerin artmasına yol açtığı görülmektedir. Bu noktada ülkelerin yenilenebilir enerji kaynaklarına geçiş yapması, kripto para madenciliği faaliyetlerinin karbon emisyonları üzerindeki etkisinin düzenli olarak raporlanması ve izlenmesi önem arz etmektedir.

Anahtar Kelimeler: *Kripto Ticareti, Karbon Emisyonları, Uluslararası Ticaret, Enerji Kullanımı, Yol Analizi*
JEL Sınıflandırması: *C32, F18, Q56*

[1] *This study was partially presented at the X. Yıldız International Social Sciences Congress held on 21-22 December 2023 and published electronically as an abstract.*

[2] *Dr., Çağ University, ssuzanoguz@gmail.com, ORCID: 0000-0003-4876-3173*

Makalenin Geliş Tarihi (Recieved Date): 23.02.2024
Araştırma Makalesi *Yayına Kabul Tarihi (Acceptance Date): 19.06.2024*

Oğuz, S. (2024). Analysis of the Impact of Crypto Trading on Carbon Emissions Using Structural Equation Modelling. *Uluslararası İktisadi ve İdari İncelemeler Dergisi*, 44, 113-124. https://doi.org/10.18092/ulikidince.1441825

1. Introduction

Although electronic payments in electronic trade are generally smooth, the system has some inherent weaknesses with financial third parties. On the other hand, mediation processes increase total transaction costs and limit the size of transactions. These costs and payment uncertainties can be avoided in face-to-face transactions using physical money, but a mechanism is required to make payments over a communication channel without a trusted party (Nakamoto, 2008: 1). Security in an information system is highly complex in the absence of auditing and a verification mechanism. To solve this problem, Nakamoto introduced two new concepts, the first of which is Bitcoin, a virtual cryptocurrency. Coins are secured by users of decentralized Peer-to-Peer (P2P) systems that have developed a verifiable and auditable network. The second concept, blockchain, is more popular than cryptocurrency (Namasudra et al., 2021: 1497).

The recent surge in interest in cryptocurrencies has prompted discussions on whether decentralised digital currency can rival traditional fiat currency as a medium of exchange. Bitcoin, introduced by Nakamoto in 2009, is a completely decentralised cryptocurrency traded solely among its users, without any control from central banks or governments. Cryptocurrencies have rapidly gained market acceptance and experienced significant development despite being a relatively new concept. In recent years, many funds and asset managers have started to include cryptocurrency-related assets in their portfolios and trading strategies (Fang et al., 2022: 4). Currently, there are hundreds of cryptocurrencies, and their technological infrastructure is based on a ledger called blockchain, which digitally records transactions. The addition of blocks to the chain is a competitive and computationally intensive process that requires a significant amount of energy input (Krause and Tolaymat, 2018: 711; Schinckus, 2020: 355). The energy consumption of cryptocurrencies, especially Bitcoin, has sparked a heated debate in both academic literature and the general public. Bitcoin is a digital currency based on a cryptographically secure distributed ledger and is the first and most well-known example of blockchain applications. The process of verifying ownership and transactions, known as 'mining', is computationally intensive and requires specific hardware as well as significant amounts of electricity (Gallersdörfer et al., 2020: 1843).

Blockchain systems, also referred to as distributed ledger technology, allow users to record and share a common view of the system's state over a distributed network (Meunier, 2018: 23). Cryptocurrencies, such as Bitcoin, operate on a peer-to-peer network structure. Each peer maintains a complete transaction history, and the balance of each account is recorded (Fang et al., 2022: 4). A blockchain is a collection of immutable data records with timestamps managed by a network of machines that are not owned by any single entity. Each of these data blocks is secured using cryptographic principles and linked together in a chain (Fang et al., 2022: 4).

Today, a great deal of interest in blockchain technology is generally focused on financial services; however, there are uncertainties about its impact on non-financial service companies, its potential impact on business models, and how it can affect value creation and transmission processes. On the other hand, it is believed that blockchain technologies will challenge the traditional business model and open new doors to value creation (Morkunas et al., 2019: 295). In his study, Truby (2018) emphasizes the positive effects of blockchains on accountability and community-based reporting, while also highlighting that they can promote cryptocurrency solutions for technology development, finance.

Economies specialize in sectors where they have a competitive advantage. Therefore, the impact of trade liberalization on environmental pollution in the local economy depends on whether it expands pollution-intensive activities (Gasimli et al., 2019: 6). However, the increase in international trade is likely to lead to higher energy consumption and carbon emissions in the transport sector.

The digital transformation of all sectors, from government to households, has been triggered by developments in information technology and industrial revolutions. This transformation has led to the development of cryptocurrency, which supports international trade and economic growth. It allows for additional resources to be attracted to the expansion of smart and green technologies to decarbonize this growth (Miśkiewicz et al., 2022: 1). International trade enables a country's domestic industrial sector to expand more rapidly than in a closed economy. Furthermore, increasing openness through trade agreements between countries stimulates economic growth (Ling et al., 2020: 691). Cryptocurrencies, as digital assets that cross borders, can make international trade faster and more efficient. Lower transaction costs compared to traditional currencies and fast transaction processes in cross-border payments facilitate the international trade of cryptocurrencies. On the other hand, trade involves the buying and selling of goods and services between different countries, and this process is often associated with energy-intensive industries. In particular, high energy consumption is often required for trading activities such as production, transport and storage.

The release of carbon emissions into the natural environment endangers both the global ecosystem and human life. Concerns about environmental sustainability and toxic emissions are raised by the rapidly increasing growth of crypto trading, the high intensity of modern technology, and the rapidly changing technological needs of people (Mohsin et al., 2023: 651). Cryptocurrencies are becoming increasingly significant in the global financial system due to their decentralised structure and absence of government supervision. However, this autonomy raises significant environmental concerns, primarily due to the energy-intensive mining process. Crypto mining produces significant amounts of energy and carbon emissions. It serves as the foundation for creating new cryptocurrencies and verifying transactions (Anandhabalaji et al., 2024: 1).

Research into the relationship between energy usage and environmental issues is crucial in the modern world. This study aims to investigate the relationship between cryptocurrency trading and carbon emissions, considering the mediating effects of energy use and international trade. Identifying the moderating impacts of international trade and energy use on carbon emissions can inform the development of effective policy approaches to combat climate change. In this context path analysis a component of Structural Equation Modeling (SEM) was conducted using data from 20 countries with high cryptocurrency trade volumes between 2014 and 2021. The study aims to investigate the potential impact of cryptocurrency trading on the environment and guide policymakers for informed decision-making in this field.

2. Literature Review

The objectives of sustainable development, environmental sustainability, and energy sustainability are seriously threatened by the speed at which the environment is deteriorating and by climate change (Mehboob et al., 2024; 180). Environmental factors caused by climate change are recognised as one of the global challenges with significant impacts on human welfare and the economy. These factors can seriously affect the living conditions of developing countries in particular. The lack of adequate investment in the necessary resources to mitigate and prevent the effects of climate change causes countries to be more exposed to these negative effects. In this context, there is a serious need to control human activities to prevent climate change (Al Sadawi et al., 2021: 1). The increase in energy consumption and carbon emissions is one of the most important areas of global warming discussions. In December 1997, the Kyoto Protocol to the United Nations (UN) climate change convention established that the determining factor until the third millennium of the Kyoto Protocol is environmental quality to determine or achieve sustainable development (Waheed et al., 2019: 1103).

A global challenge facing developed and developing countries is to combine sustainable economic development with a secure environmental system. Energy efficiency has a critical importance in achieving sustainable economic growth while reducing ecological impacts (Shah et al., 2023; 1). In the literature, there are studies examining the relationship between energy consumption and carbon emissions with various methods by including different variables (Zhang and Cheng, 2009; Bernard and Mandal, 2016; Esso and Keho, 2016; Gasimli et al., 2019; Waheed et al., 2019; Awodumi and Adewuyi, 2020; Khan et al, 2020; Ling et al, 2020; Muhammed et al, 2020; Schinckus et al, 2020; Khan et al, 2021; Nathaniel et al, 2021; Alqaralleh, 2021; Ali et al, 2021; Sousa and Bogas, 2022; Lee et al, 2023; Koçak and Uçan 2023; Hong and Zhang; 2023; Fatima et al, 2023; Song et al, 2023; Shah et al, 2023; Liu et al, 2023).

Zhang and Cheng (2009) used the Granger causality test to analyze the relationship between economic growth, energy consumption, and carbon emissions in China by using data from 1960 to 2007, The empirical findings demonstrate that, over time, there is a unidirectional Granger causality from energy consumption to carbon emissions as well as a unidirectional Granger causation from GDP to energy consumption. The results imply that energy use and carbon emissions do not propel economic expansion.

Esso and Keho (2016) investigated the causal long-term relationships between economic development, carbon dioxide emissions, and energy consumption between 1971 and 2010 in 12 Sub-Saharan African countries. The empirical results show a favorable correlation between energy use and long-term economic growth. Yet, this connection causes carbon dioxide emissions throughout the majority of Sub-Saharan Africa. Granger causality studies show a short-term bidirectional causal relationship between economic growth and carbon emissions.

Schinckus et al. (2020) investigated the impact of cryptocurrency trading volumes on energy consumption in the USA between 2014 and 2017. Energy consumption and the volume of cryptocurrency trades were found to be positively correlated by the study. Furthermore, the results suggest that energy consumption and cryptocurrency trade are causally and cointegrated related.

Muhamed et al. (2020) conducted a panel data analysis to investigate the impact of urbanization and international trade on carbon emissions in 65 Belt and Road Initiative countries from 2000-2016. The study's findings show that while exports reduced carbon emissions in high- and low-income countries, they increase them in lower-middle-income countries. However, research has shown that the effect of imports on carbon emissions varies depending on the GDP of the country. It has been demonstrated that imports increase carbon emissions in low-income countries while generally decrease them in high- and middle-class ones.

Liu et al. (2023) investigated the relationship between energy consumption, economic development, urbanization, and carbon emissions using panel cointegration tests and pooled average group (PMG-ARDL) approaches with China's 1995-2020 panel data. The results of the study indicate that the quality of the environment is not significantly impacted by urbanization. Nonetheless, it has been demonstrated that energy use harms the ecosystem significantly over time as well as right once. Moreover, research has shown that environmental deterioration is impacted over time by economic expansion.

In their analysis of data from the United States, Seychelles, South Korea, Japan, and the United Kingdom from 2013-2021, Koçak and Uçan (2023) examined the relationship between economic growth, energy consumption, cryptocurrency trade, and carbon emissions using panel data analysis. The analysis revealed that cryptocurrency transactions and energy consumption led to an increase in carbon emissions for the relevant countries. However, no significant relationship was found between GDP and carbon emissions.

Hong and Zhang (2023) examined the dynamic effects of Bitcoin trading, economic growth and energy use on carbon emissions emissions in 20 emerging economies that trade Bitcoin using data for the period 2013-2020 with panel data analysis. The findings show that Bitcoin trading, economic growth and energy use increase carbon emissions in the long run and there is a bidirectional relationship between these three factors.

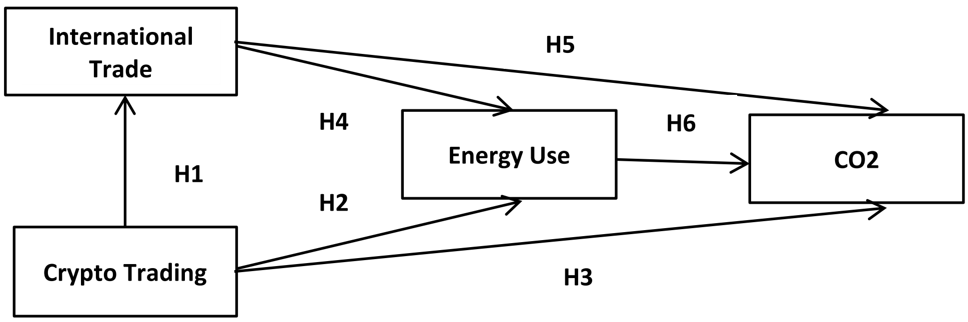
When the studies are evaluated in general, it is seen that there is a positive relationship between energy consumption, carbon emissions, and other macroeconomic variables. In the industrialisation process and with the increase in modern living standards, energy demand also increases, which contributes to the increase in carbon emissions from energy use. On the other hand, low efficient energy production and utilisation systems also lead to an increase in carbon emissions.

3. Method And Analysis

SEM is a method generally used to explain multiple statistical relationships simultaneously through visualisation and model validation. This method is an improved version of traditional linear modelling methods such as multiple regression analysis and analysis of variance, which provide the solution of complex models. SEM can also be defined as combining factor analyses and multiple regression analyses at the same time (Dash and Paul, 2021: 1). With its advantages such as its flexibility and general validity, SEM has become extremely popular in many disciplines, especially in recent years (Mueller and Hancock, 2018; Dash and Paul, 2021). SEM is increasingly used in social sciences as a preferred technique for concept and theory development, especially in the management discipline (Mia et al., 2019: 56). The complex theoretical model developed with this method is usually linked to the collected data and this link is called model- data fit.

The application of SEM permits a more detailed analysis of the relationships between variables, with the consideration of both direct and indirect effects within the same model. Path analysis represents a component of SEM and is employed to identify the relationships between variables through the use of a path diagram. Path analysis is known as an effective method that allows the evaluation of the relationships between variables from an integrated perspective and is used to reveal the indirect and direct effects of variables on each other. This method is used to measure the fit of a theoretical model and provides the opportunity to evaluate how well the data are compatible with the theoretical model. Firstly, the model proposed within the scope of the research, the relationships between variables and the proposed paths are shown. The model proposed within the scope of this study is shown in Figure 1.

Figure 1: **Proposed Research Model**



The hypotheses of the proposed model of the research are as follows.

H1. Crypto trading has a positive impact on international trade.
H2. Crypto trading has a positive effect on energy use.
H3. Crypto trading trading has a positive effect on CO2.
H4. International trade has a positive effect on energy use.
H5. International trade has a positive effect on CO2.
H6. Energy use has a positive effect on CO2.

This study uses data from the 20 countries with the highest cryptocurrency transaction volume between 2014 and 2021. The secondary data used in this study was prepared by international institutions and has been tested for reliability. IBM SPSS Amos 29 was used for the analyses, which provides all the necessary tools to create and run graphs and path diagrams

(Byrne, 2001: 57). The countries analysed and the dataset used in the study are presented in Table 1 and Table 2, respectively.

Table 1: **Countries Included in the Scope of the Analysis**

Country Name	Country Name
United States of America	Liechtenstein
Seychelles	Panama
South Korea	United Kingdom
Malta	Cayman Islands
Antigua and Barbuda	Holland
Japan	Estonia
Hong Kong	Slovenia
Bahamas	Mexican
Singapore	Indonesia
Türkiye	Thailand

Table 2: **Data Set of the Study**

Variable Name	Variable Description	Source
Crypto Trading	International Blockchain Transactions (incoming+outgoing)	Crystal Blockchain
International Trade	Trade (%GDP)	World Bank
Energy Use	Energy consumption per capita in oil equivalent	World Bank - Our World in Data
CO2	Carbon emissions per capita (metric tonnes)	World Bank

3.1. Analysis Findings

Correlation analysis was performed as the first step within the scope of the study. This method evaluates the relationship between variables using a correlation coefficient that ranges from -1 to +1. The strength of the relationship between variables is directly proportional to the magnitude of the absolute value of the correlation coefficient. Table 3 shows the correlation values of the variables studied.

Table 3: **Correlation Analysis**

Variable Name	Crypto Trading	International Trade	Energy Use	CO2
Crypto Trading	1.000			
International Trade	0.64	1.000		
Energy Use	0.71	0.78	1.000	
CO2	0.73	0.75	0.76	1.000

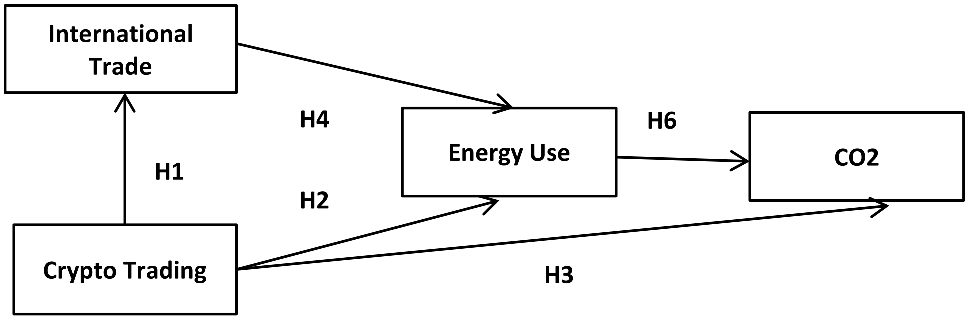
Table 3 shows that cryptocurrency trade has a positive correlation of 0.64 with international trade, 0.71 with energy use, and 0.73 with CO2. It is concluded that the highest correlation coefficient is between international trade and energy use with a value of 0.78. After the correlation analysis, the hypothesis test results of the model proposed within the scope of the study are shown in Table 4.

Table 4: **Hypothesis Test Results of the Proposed Model**

Hypothesis Ru	Standard β	P	Accept/Reject
H1	.107	.005	Accepted
H2	.126	.002	Accepted
H3	.089	.007	Accepted
H4	.092	.006	Accepted
H5	.055	.663	Rejected
H6	.018	.010	Accepted

When Table 4 is analysed, it is seen that H5, which is formed for the positive effect of international trade on carbon emissions, is not supported, while the other five hypotheses are supported. In SEM, the model is redefined by removing the unsupported hypotheses from the model and the analyses are continued with the accepted model. The model accepted within the scope of the study is as shown in Figure 2.

Figure 2: **Accepted Model**



After adopting the SEM model, the values of the model fit indices are evaluated. Model fit indices are commonly used to simplify the structural model and improve its fit (Liu et al., 2020: 9). Researchers can evaluate how well the structural models match their data with the help of these indices, which offer useful information (Stone, 2021: 1). Table 5 lists the approved model fit values for this study as well as the most often used model fit indices in SEM research.

Table 5: **Goodness of Fit Values of the Accepted Model**

Goodness of Fit Indices	Accepted Fit Range	Model Fit Value
χ2/sd (CMIN/DF)	≤ 5	2.18
CFI	.90≤CFI≤1.00	0.97
NFI	.90≤NFI≤1.00	0.98
RMSEA	.00≤RMSA≤.08	0.06

All model fit index values are clearly within acceptable ranges when looking at Table 5 (Shadfar and Malekmohammadi, 2013; Zaini et al., 2020; Stone, 2021; Oğuz, 2024). Therefore, it can be said that no adjustments are required to the model that was approved for use in the study because it is compatible with the data that was used.

SEM analyses the relationships between variables in three different aspects. Firstly, direct effect refers to the situation where one variable has a direct effect on another variable without any intermediary. Secondly, indirect effect refers to the situation in which one variable has an effect on another variable through an intermediary. The sum of these two effects shows the total effect level. The types and levels of effects that emerged in the analysis of the relationships between variables are shown in Table 6.

When Table 6 is analysed, it is seen that cryptocurrency trade has an impact of 0.67 on international trade, 0.73 on energy use, and 0.86 on CO2 in terms of the total impact. When the direct effects are analysed, it is determined that cryptocurrency trade has an impact of 0.67 on international trade, 0.19 on energy use, and 0.63 on CO2. Finally, when the indirect effects are analysed, it is seen that cryptocurrency trade has an effect of 0.54 units on energy use and 0.23 units on CO2. Indirect effect findings show that cryptocurrency trade can affect energy consumption and CO2 emissions along with its impact on international trade. Because cryptocurrencies lead to an increase in international trade and can increase energy consumption and CO2 emissions.

Table 6: **Total, Direct, and Indirect Effects between Variables in the Accepted Model**

Standardised Total Effects			
Variables	**CryptoTrading**	**International Trade**	**Energy Use**
International Trade	0.67	0	0
Energy Use	0.73	0.80	0
CO2	0.86	0.25	0.31
Standardised Direct Effects			
Variables	**CryptoTrading**	**International Trade**	**Enerji Kullanımı**
International Trade	0.67	0	0
Energy Use	0.19	0.80	0
CO2	0.63	0	0.31
Standardised Indirect Effects			
Variables	**CryptoTrading**	**International Trade**	**Energy Use**
International Trade	0	0	0
Energy Use	0.54	0	0
CO2	0.23	0.25	0

4. Conclusion

With the rapidly changing technological requirements of individuals and their growing interest in modern technologies, crypto transactions bring issues such as environmental sustainability and increased emissions to the forefront in countries. This process requires the continuous operation of energy-intensive hardware, thus increasing energy consumption. The increase in the amount of carbon emissions released into the natural environment jeopardises both the global ecosystem and human life. Therefore, mitigation of climate change and carbon emissions are among the critical targets for the protection of human life and environmental sustainability.

With the development of technology and regulation, the role of cryptocurrencies in international trade is also increasing. The speed and cost advantages of cryptocurrencies in interbank transactions are encouraging their use in international trade. As a result, the international community is intensifying its efforts to regulate the role of cryptocurrencies in international trade. The aim of this study is to examine the relationship between crypto trading and carbon emissions with the mediating roles of international trade and energy use. In order to understand and analyse these relationships, path analysis was performed with SEM using the data of 20 countries with high crypto trade volume for the years 2014-2021. The findings of the analysis show that crypto trading has a positive and significant effect on carbon emissions. It is also concluded that international trade and energy use mediate the relationship between crypto trading and carbon emissions. During the production process, a large amount of energy is needed to process raw materials and produce products. In addition, international trade activities, such as overseas transport, involve the use of fossil fuels in particular, which increases energy use.

This study is expected to make important contributions in both theoretical and practical terms by analysing the relationship between crypto trading and carbon emissions in depth. The study empirically tests the environmental impacts of crypto trading, contributing to the literature in this field. The growth and popularity of crypto trading's impact on environmental concerns, such as carbon emissions, enriches theoretical frameworks in the financial and environmental fields. The findings provide policymakers with actionable recommendations to achieve environmental sustainability goals. The positive relationship between crypto trading and carbon emissions highlights the need for regulations and policies in this area. Encouraging the transition to renewable energy sources is crucial. Governments can incentivise green energy investments through tax breaks and other economic instruments. Furthermore, stricter regulatory frameworks should be implemented for crypto trading and mining activities, and they should be regularly reported, taking into account their environmental impact. Additionally, governments can enhance regulations and conduct more rigorous audits to align the crypto industry with environmental sustainability standards.

References

Al Sadawi, A., Madani, B., Saboor, S., Ndiaye, M. and Abu-Lebdeh, G. (2021). A Comprehensive Hierarchical Blockchain System for Carbon Emission Trading Utilizing Blockchain of Things and Smart Contract. *Technological Forecasting and Social Change*, *173*, 121124.

Ali, M. U., Gong, Z. M., Ali, M. U., Wu, X. and Yao, C. (2021). Fossil Energy Consumption, Economic Development, inward FDI impact on CO2 Emissions in Pakistan: Testing EKC Hypothesis Through ARDL Model. *International Journal of Finance & Economics,* 26(3), 3210–3221.

Alqaralleh, H. (2021). On the Nexus of CO2 Emissions and Renewable and Nonrenewable Energy Consumption in Europe: A New Insight from Panel Smooth Transition. *Energy & Environment*, 32(3), 443–457

Anandhabalaji, V., Babu, M. and Brintha, R. (2024). Energy Consumption by Cryptocurrency: A Bibliometric Analysis Revealing Research Trends and Insights. *Energy Nexus*, 100274.

Awodumi, O. B. and Adewuyi, A. O. (2020). The Role of Non-Renewable Energy Consumption in Economic Growth and Carbon Emission: Evidence from Oil Producing Economies in Africa. *Energy Strategy Reviews*, *27*, 100434.

Bernard, J. and Mandal, S. K. (2016). The Impact of Trade Openness on Environmental Quality: An Empirical Analysis of Emerging and Developing Economies. *WIT Transactions on Ecology and the Environment*, *203*, 195-208.

Bouraoui, T. (2020). The Drivers of Bitcoin Trading Volume in Selected Emerging Countries. *The Quarterly Review of Economics and Finance*, *76*, 218-229.

Byrne, B. M. (2001). Structural Equation Modeling with AMOS, EQS, And LISREL: Comparative Approaches to Testing for The Factorial Validity of A Measuring Instrument. *International journal of testing*, *1*(1), 55-86.

Crystal Blockchain (2023). Crystal Blockchain's Year in Review 2021, https://crystalintelligence .com/, (accessed 18 December 2023).

Dash, G. and Paul, J. (2021). CB-SEM vs PLS-SEM Methods for Research in Social Sciences and Technology Forecasting. *Technological Forecasting and Social Change*, *173*, 121092.

Esso, L. J. and Keho, Y. (2016). Energy Consumption, Economic Growth and Carbon Emissions: Cointegration and Causality Evidence from Selected African Countries. *Energy*, *114*, 492-497.

Fang, F., Ventre, C., Basios, M., Kanthan, L., Martinez-Rego, D., Wu, F. and Li, L. (2022). Cryptocurrency Trading: A Comprehensive Survey. *Financial Innovation*, *8*(1), 1-59.

Farouk, A., Alahmadi, A., Ghose, S., & Mashatan, A. (2020). Blockchain Platform for Industrial Healthcare: Vision and Future Opportunities. *Computer Communications*, *154*, 223-235.

Fatima, T., Shahzad, U. and Cui, L. (2021). Renewable and Nonrenewable Energy Consumption, Trade and CO2 Emissions in High Emitter Countries: Does The Income Level Matter?. *Journal of Environmental Planning and Management*, *64*(7), 1227-1251.

Gallersdörfer, U., Klaaßen, L. and Stoll, C. (2020). Energy Consumption of Cryptocurrencies Beyond Bitcoin. *Joule*, *4*(9), 1843-1846.

Gasimli, O., Haq, I. U., Naradda Gamage, S. K., Shihadeh, F., Rajapakshe, P. S. K. and Shafiq, M. (2019). Energy, Trade, Urbanization and Environmental Degradation Nexus in Sri Lanka: Bounds Testing Approach. *Energies*, *12*(9), 1655.

Hong, H. and Zhang, C. (2023). Bitcoin Trading, Economic Growth, Energy Use, and CO2 Emissions: An Advanced Panel Study of Emerging Market Economies. *International Review of Economics & Finance*, 87, 519-531.

Khan, H., Weili, L., Khan, I. and Khamphengxay, S. (2021). Renewable Energy Consumption, Trade Openness, and Environmental Degradation: A Panel Data Analysis of Developing and Developed Countries. *Mathematical Problems in Engineering*, *2021*, 1-13.

Khan, Z., Ali, S., Umar, M., Kirikkaleli, D. and Jiao, Z. (2020). Consumption-Based Carbon Emissions and International Trade in G7 Countries: The Role of Environmental Innovation and Renewable Energy. *Science of the Total Environment*, *730*, 138945.

Koçak, E. and Uçan, O. (2023). Kripto Para Ticaretinin Çevre Kirliliği Üzerine Etkileri: Panel Veri Analizi. *Journal of Politics Economy and Management*, *6*(2), 95-107.

Krause, M. J. And Tolaymat, T. (2018). Quantification of Energy and Carbon Costs for Mining Cryptocurrencies. *Nature Sustainability*, *1*(11), 711-718.

Lee, C. C., Zhang, J. and Hou, S. (2023). The impact of Reginal Renewable Energy Development on Environmental Sustainability in China. *Resources Policy,* 80, 103245.

Ling, T. Y., Ab-Rahim, R. and Mohd-Kamal, K. A. (2020). Trade Openness and Environmental Degradation in Asean-5 Countries. *International Journal of Academic Research in Business and Social Sciences*, *10*(2), 691-707.

Liu, H., Wong, W. K., Cong, P. T., Nassani, A. A., Haffar, M. and Abu-Rumman, A. (2023). Linkage Among Urbanization, Energy Consumption, Economic Growth and Carbon Emissions. Panel Data Analysis for China Using ARDL Model. *Fuel*, *332*, 126122.

Liu, J., Yi, Y. and Wang, X. (2020). Exploring Factors Influencing Construction Waste Reduction: A Structural Equation Modeling Approach. *Journal of Cleaner Production*, *276*, 123185.

Marmora, P. (2021). Currency Substitution in The Shadow Economy: International Panel Evidence Using Local Bitcoin Trade Volume. *Economics Letters*, *205*, 109926.

Mehboob, M. Y., Ma, B., Sadiq, M. and Zhang, Y. (2024). Does Nuclear Energy Reduce Consumption-Based Carbon Emissions: The Role of Environmental Taxes and Trade Globalization in Highest Carbon Emitting Countries. *Nuclear Engineering and Technology*, *56*(1), 180-188.

Meunier, S. (2018). Blockchain 101: What is Blockchain And How Does This Revolutionary Technology Work?. In *Transforming climate finance and green investment with Blockchains*, 23-34. Academic Press.

Mia, M. M., Majri, Y. and Rahman, I. K. A. (2019). Covariance Based-Structural Equation Modeling (CB-SEM) Using AMOS in Management Research. *Journal of Business and Management*, *21*(1), 56-61.

Miśkiewicz, R., Matan, K. and Karnowski, J. (2022). The Role of Crypto Trading in The Economy, Renewable Energy Consumption and Ecological Degradation. *Energies*, *15*(10), 3805.

Mohsin, M., Naseem, S., Zia-ur-Rehman, M., Baig, S. A. and Salamat, S. (2023). The Crypto-Trade Volume, GDP, Energy Use, and Environmental Degradation Sustainability: An Analysis of The Top 20 Crypto-Trader Countries. *International Journal of Finance & Economics*, *28*(1), 651-667.

Morkunas, V. J., Paschen, J. and Boon, E. (2019). How Blockchain Technologies Impact Your Business Model. *Business Horizons*, *62*(3), 295-306.

Muhammad, S., Long, X., Salman, M. and Dauda, L. (2020). Effect of Urbanization and International Trade on CO2 Emissions Across 65 Belt And Road İnitiative Countries. *Energy*, *196*, 117102.

Nakamoto, S. (2008). Bitcoin: A Peer-to-Peer Electronic Cash System. *Decentralized business review*.

Namasudra, S., Deka, G. C., Johri, P., Hosseinpour, M. and Gandomi, A. H. (2021). The Revolution of Blockchain: State-of-the-art and Research Challenges. *Archives of Computational Methods in Engineering*, *28*, 1497-1515.

Nathaniel, S. P., Murshed, M. and Bassim, M. (2021). The Nexus between Economic Growth, Energy Use, International Trade and Ecological Footprints: The Role Of Environmental Regulations in N11 Countries. *Energy, Ecology and Environment*, *6*(6), 496-512.

Oğuz, S. (2024). The Link Between Trade Openness, Economic Growth, Energy Use and Carbon Emissions: Analysis with a Conceptual Model Proposal. *Sosyoekonomi*, 32(60), 181-195.

Our World in Data (2023). Data Explorers, https://ourworldindata.org/, (accessed 30 December 2023).

Schinckus, C., Canh, N. P. and Ling, C. H. (2020). Crypto-currencies Trading and Energy Consumption. *International Journal of Energy Economics and Policy*, *10*(3), 355-364.

Shadfar, S. and Malekmohammadi, I. (2013). Application of Structural Equation Modeling (SEM) in Restructuring State İntervention Strategies Toward Paddy Production Development. *International Journal of Academic Research in Business and Social Sciences,* 3(12), 576.

Shah, W. U. H., Hao, G., Yan, H., Zhu, N., Yasmeen, R. and Dincă, G. (2023). Role of Renewable, Non-Renewable Energy Consumption and Carbon Emission in Energy Efficiency and Productivity Change: Evidence from G20 Economies. *Geoscience Frontiers*, 101631.

Song, S., Zhang, L. and Ma, Y. (2023). Evaluating the impacts of Technological Progress on Agricultural Energy Consumption and Carbon Emissions Based on Multi-Scenario Analysis. *Environmental Science and Pollution Research*, *30*(6), 16673-16686.

Sousa, V. and Bogas, J. A. (2021). Comparison of Energy Consumption and Carbon Emissions from Clinker and Recycled Cement Production. *Journal of cleaner production*, *306*, 127277.

Stone, B. M. (2021). The Ethical use of Fit İndices in Structural Equation Modeling: Recommendations for Psychologists. *Frontiers in psychology*, *12*, 783226.

Truby, J. (2018). Using Bitcoin Technology to Combat Climate Change. Nat. *Middle East*, *19*.

Waheed, R., Sarwar, S. and Wei, C. (2019). The Survey Of Economic Growth, Energy Consumption and Carbon Emission. *Energy Reports*, *5*, 1103-1115.

World Bank (2023). World Bank Open Data, https://data.worldbank.org/, (accessed 30 December 2023).

Zaini, B. J., Yusof, Z. M., Mansor, R., Zainuddin, N., Adlee, N. F. K. and Ahmad, H. N. L. (2020). Constructing Motivation for Sports Activities among College Students Using CB-SEM Path Model. *European Journal of Molecular & Clinical Medicine*, *7*, 2299-2313.

Zhang, X. P. and Cheng, X. M. (2009). Energy Consumption, Carbon Emissions, and Economic Growth in China. *Ecological economics*, *68*(10), 2706-2712.