Research in International Business and Finance 66 (2023) 102060

Contents lists available at ScienceDirect

Research in International Business and Finance

journal homepage: www.elsevier.com/locate/ribaf

The ripple effects of CBDC-related news on Bitcoin returns: Insights from the DCC-GARCH model

Isik Akin [a], Muhammad Zubair Khan [b], Affan Hameed [c,*], Kaouthar Chebbi [d], Hakan Satiroglu [a]

[a] Bath Spa University, Bath Business School, Newton Park Campus, Bath, UK
[b] Institute of Management Sciences, University of Science and Technology Bannu, Bannu, Pakistan
[c] Fashion Business School, London College of Fashion, University of Arts London, London, UK
[d] Department of Finance, School of Business, King Faisal University, Al-Hasa, Saudi Arabia

ARTICLE INFO

Keywords:
Central Bank Digital Currency (CBDC)
CBDC uncertainty index
CBDC attention index
Bitcoin
Cryptocurrencies
Time series

ABSTRACT

Central bank digital currencies (CBDCs) have emerged as a potential substitute for current payment methods, and, as such, major announcements, events and policy discussions regarding CBDCs have the potential to influence cryptocurrency returns. In light of this, the present study undertakes an in-depth analysis of the CoinMarketCap data between August 1, 2017 and April 1, 2022 by implementing the dynamic conditional correlation-generalized autoregressive conditional heteroskedasticity (DCC-GARCH) model. The study reveals a noteworthy influence of news and events related to CBDCs on Bitcoin returns. Precisely, CBDC uncertainty index and CBDC attention index have resulted in significant fluctuations in Bitcoin returns, indicating that positive news can result in significant Bitcoin returns. The findings suggest that future expectations of investors regarding cryptocurrencies are shaped by CBDC-related news and events.

1. Introduction

The advent of digital currency during the 1990s ushered in a new era of peer-to-peer (P2P) payments that do not require bank authorization. The first instance of P2P payments was facilitated by stored-value cards, allowing users to store a specific amount of monetary value on a card and subsequently employ it to transact with others without the intervention of a bank (Clemons and Row, 1992). Since the emergence of Bitcoin, cryptocurrencies, which are digital coins that utilize blockchain technology, have garnered significant interest from investors in financial markets (Yermack, 2017). These digital currencies represent the convergence of technology and economics and possess the capacity to solve socioeconomic issues such as economic instability, inflation, the absence of widespread financial services, and misconduct by financial institutions (Hendrickson et al., 2016).

Bitcoin is a digital currency that enables direct transactions between individuals through cryptography and advanced information technology. The encryption mechanisms utilized by Bitcoin are both a technical innovation and a reflection of the underlying values of social solidarity and mutual support. These values are grounded in the principles of P2P networks and open-source technology, as expounded by Scott (2016). Bitcoin became associated with various groups of people, including speculators, profit-oriented entrepreneurs, market fundamentalists, and libertarians who embrace technology (Yelowitz and Wilson, 2015). This virtual currency seems to have been introduced as a reaction to environmental issues. Its rising popularity is evidence that it is the best way to handle current

* Corresponding author.
E-mail address: a.hameed@fashion.arts.ac.uk (A. Hameed).

https://doi.org/10.1016/j.ribaf.2023.102060
Received 31 August 2022; Received in revised form 30 June 2023; Accepted 20 August 2023
Available online 22 August 2023

social problems. However, current efforts by the authorities to maintain control over the market and limit the growth of virtual currencies are causing confusion and uncertainty (Mikołajewicz-Woźniak and Scheibe, 2015).

Bitcoin harnesses cutting-edge technology with untapped potential, though its full scope remains unrealized. Nevertheless, it presently delivers services comparable to conventional assets. The blockchain has the potential to reduce costs and decrease the time required for negotiations, which could result in a significant increase in the liquidity of the securities market (Aste, 2016). Bitcoin's acceptance steadily grown across diverse sectors within the global financial landscape. For instance, the New York Stock Exchange has established the Bitcoin index. This is complemented by the presence of numerous Bitcoin automatic teller machines (ATMs) across four continents. Additionally, well-known merchants such as Dell, Newegg, and Overstock enhance this landscape by embracing Bitcoin payments. Thus, Bitcoin has evolved from an obscure internet phenomenon into a successful fintech invention in less than 10 years, upending established monetary and payment systems (Böhme et al., 2015).

Numerous academic studies on the creation of cryptocurrency offer theoretical models and discuss a variety of factors that could affect cryptocurrency prices (Ciaian et al., 2016; Urquhart, 2018; Feng et al., 2018), but little research has been conducted on the financial elements of cryptocurrency. Several studies have investigated the correlation between the major cryptocurrencies. This study addresses this void by examining the link between central bank digital currencies (CBDCs) and Bitcoin returns.

According to Morgan (2022), crypto investors worldwide are showing a significant amount of interest in CBDCs. The development of CBDCs was prompted by the waning popularity of fiat currencies for transactions driven by the ascent of fintech and digital currencies. The shift can be attributed to the widespread adoption of e-commerce and contactless payment methods. Cryptocurrencies differ from CBDCs, as the former are not issued by governments, whereas CBDCs are issued by central banks in an electronic (or digital) form that combines cryptography and digital ledger technology (De Lis and Sebastian, 2019). Furthermore, CBDCs can be utilized by individuals for personal transactions, bybusinesses for payments, and by anyone as a means to store value (Echarte Fernández et al., 2021).

Even though CBDCs do not take the form of physical notes or coins, they remain linked to the domestic currency of the country or region in which they are issued.[1] It is predicted that the introduction of CBDCs will have a transformative impact on how individuals, businesses, and governments conduct transactions that may promote financial development, especially in terms of financial inclusion. The Bahamas, Nigeria, and China have been among the first countries to adopt CBDCs, while others, such as Sweden, are currently moving toward its implementation (Allen et al., 2022; Mzoughi et al., 2022).

CBDCs offer a number of benefits, including cost efficiency and improved security against counterfeiting. In addition, CBDCs are subject to regulation and monetary supervision, which further enhances their appeal (Sun et al., 2017). However, while previous research has focused on the pros and cons of CBDC adoption and its overall implications, there has been limited research into the specific effects of CBDCs on financial markets. As digital currencies gain popularity, researchers have been turning their attention to examining the determinants of Bitcoin prices. It is crucial to understand the factors that influence Bitcoin returns on the primary Bitcoin exchanges, as this has significant theoretical and practical implications (Mai et al., 2018).

Investors must have specific indicators to predict future price changes and estimate potential profits. To mitigate risks to financial stability, companies can create their own digital currencies with an initial coin offering (ICO), adopt Bitcoin, or do both. Therefore, it is essential to understand the elements that impact Bitcoin's volatility, as highlighted by various news sources (Jopson, 2016; Mai et al., 2018; Ren and Culpan, 2017).

There has been a scarcity of studies exploring the potential influence of CBDCs on Bitcoin returns. However, one notable study conducted by Chohan (2022) examined whether CBDCs supplement or replace Bitcoin. The author proposed that CBDCs could decrease the demand for Bitcoin, given that CBDCs may provide a more dependable and secure substitute. This paper postulates that CBDCs may exert both favorable and unfavorable influences on Bitcoin returns. Although CBDCs may be detrimental to cryptocurrency in the short term, in the long term, as digital currencies garner greater acceptance and utility, their influence could be constructive.

This paper investigates the impact of CBDCs on the cryptocurrency market and delves into the effects that CBDCs may have on the cryptocurrency market, weighing the possibility of CBDCs being a threat to the market against the possibility that they may serve as a valuable addition to the digital currency ecosystem. Previous research on cryptocurrencies has explored various dimensions such as market capitalization, trading volume, and price. For instance, Katsiampa (2017) investigated the market capitalization and trading volume of Bitcoin, Litecoin, and Ripple, while Cheah and Fry (2015) analyzed the price and trading volume of Bitcoin. Mzoughi et al. (2022) investigated the impact of the launch of CBDCs on the Bitcoin market and discovered that it had a significant impact on the cryptocurrency market.

The study aims to address the following question: how announcements related to CBDCs influence Bitcoin returns? To tackle this inquiry, data was gathered from www.coinmarketcap.co.uk, encompassing cryptocurrencies with a market value surpassing £1 billion. The data spanned the period from August 1, 2017, to April 1, 2022.. To assess news related to CBDCs, the paper employs CBDC uncertainty index and the CBDC attention index developed by two indices to track trends and variations, both made public by Wang et al. (2022a) Moreover, the study employs a dynamic conditional correlation-generalized autoregressive conditional heteroskedasticity (DCC-GARCH) model. The results reveal that CBDC news have a positive influence on Bitcoin returns. These findings hold implications for various stakeholders, including financial securities regulators, firms, investors, and policymakers.

The paper follows this structure: the subsequent section delves into a review of pertinent literature and the formulation of hypotheses. Section 3 outlines the study's methodology, while Section 4 presents the results. Finally, Section 5 concludes the paper.

[1] https://www.bankofengland.co.uk/research/digital-currencies (accessed on 20 December 2021).

2. Literature review

2.1. Cryptocurrencies and Bitcoin

When an instrument that relies upon encryption or cryptography is created and then integrated into a blockchain database, it is commonly referred to as "crypto." In this context, the term "currency" pertains to the acceptance of a tool as a medium of exchange among its users. The European Central Bank (2015) defined virtual currency as a form of digital or electronically (e.g. magnetically) stored monetary value. Even though it is not presented as physical currency, such as notes or coins, it remains linked to and associated with the local currency of the originating country or region. This type of currency can be accepted by legal entities or individuals aside from the virtual currency issuer. Digital currencies include cryptocurrencies such as Bitcoin, Litecoin, Finance, Ethereum, and Stellar as well as non-cryptocurrencies such as in-game credits for popular multi-player online games such as World of Warcraft, credits provided by advertisers, and various other digitally stored value systems (Abu-Bakar, 2018).

Bitcoin is a digital currency that operates on a decentralized network known as blockchain. It is not backed by any government or legal entity and transactions do not rely on intermediaries (Grinberg, 2012; Foley et al., 2022). The concept of Bitcoin was first introduced in 2008 by an individual or a group using the pseudonym Satoshi Nakamoto. The principles outlined in Nakamoto's paper "Bitcoin: A Peer-to-Peer Electronic Cash System" formed the foundation for the development of Bitcoin. The identity of Nakamoto remains unknown, adding to the mystique surrounding the currency (Goodman, 2014).

Since its launch in 2008, Bitcoin has attracted the attention of media, academia, and financial markets, and it has produced an entire ecosystem of digital currencies and fundraising through ICOs without the support of governments or established financial institutions (Foley et al., 2022; De Andrés et al., 2022). Bitcoin employs a cryptographic hash function to relay transaction and enjoys superiority over traditional digital payment systems (such as Visa or Mastercard), as it is highly liquid, more economical, and highly confidential (Nica et al., 2017; Thada et al., 2019).

Bitcoin consists of an algorithm that provides users with a digital wallet so that they can transfer digital coins to each other within a virtual network (Bjerg, 2016). Bitcoin is built on a public ledger called "the blockchain," which consists of a distinct chain of virtual signatures, and individual users store those digital signatures in their digital wallets (Bjerg, 2016; Best, 2018). Owners of wallets can transfer Bitcoin to other users by generating keys for mutual approval between the recipient and the sender of the coins. This process guarantees the accuracy of transactions and leaves evidence in the form of a transaction history (Kimani et al., 2020). A user has an "address" at which to receive, store, and transmit Bitcoin, which functions like a bank account. Bitcoins are protected using public-key encryption (whereas cash might be protected by keeping it in a safe) (Best, 2018).

Private keys are unique to each Bitcoin wallet and must be kept private by the owner. With the use of this private key, the user can generate as many public keys as desired, each of which can be used to generate a public address for receiving payments in the wallet. While anybody can transfer Bitcoin to any address, only the private key's owner can spend the Bitcoin stored in the wallet associated with that address. Bitcoin addresses are anonymous because, despite being public, it is not always possible to determine which address belongs to which person. The Bitcoin sender advertises the transaction information to other network users. The published transaction details are checked by other network participants, and if the transaction seems valid, it is added to the blockchain (Best, 2018). The blockchain will need a public address of a wallet in order to transact a purchase (of cupcakes from Cups and Cakes Bakery in San Francisco, for instance). Wallet software will broadcast the transaction to the network once the user has entered the amount and destination address. This transaction is posted on the P2P Bitcoin network, where it propagates to all of the other network users after being verified by a number of checks, including whether that wallet has enough funds. A "miner" (of Bitcoin) ultimately receives the transaction and adds it to a block after receiving it. The network then accepts this block and adds it to the global blockchain. The wallet associated with the Cups and Cakes Bakery, identifiable by the address to which the Bitcoin was sent, now owns the Bitcoin (Franco, 2014).

2.2. Defining Central Bank Digital Currency (CBDC)

A CBDC is a form of digital currency that is created and issued by a central bank. Despite being digital and programmable, CBDCs operate in a similar way to traditional bank notes. There are currently two different forms of government-backed money in use: physical currency and digital balances connected to a commercial bank. If implemented, CBDCs would create a third payment option without replacing or diminishing the value of those already in place. Theoretically, policymakers might, at any time, airdrop to or remove money from individuals' digital wallets (Becher, 2022).

The Bank of England has announced a comprehensive research agenda on CBDCs, despite not currently planning to issue one of its own (Bank of England, 2016). CBDC, according to the Bank of England, is digital central bank money that is accessible to a broader range of users than only those with reserves. Unlike physical cash, a CBDC offers more capabilities for small-value transactions and operates on a structure that is distinct from conventional central bank money. These unique characteristics may make the CBDC's primary purpose different from other types of money issued by central banks. In addition, CBDCs can be interest-bearing and may provide a rate that differs from the reserve rate under reasonable conditions (Kumhof and Noone, 2018). As of May 2022, 109 nations were actively "exploring" CBDCs, according to the independent think tank the Atlantic Council. China was the first to declare a pilot program for a centralized virtual currency, and the following CBDCs have been officially launched (Becher, 2022).

2.2.1. The sand dollar

In October 2020, the first CBDC, dubbed the "sand dollar", was unveiled, representing a digital manifestation of the Bahamian

dollar. It was made accessible to only 393,000 individuals and as of March 2023 only a minuscule 0.1 % of all sand dollars were actually in circulation in the form of sand dollars.

2.2.2. E-CNY

In recent years, the People's Bank of China has launched e-CNY, a digital rendition of the yuan that competes head on with Tencent's WeChat Pay and Alipay, which are managed by the Ant Group, a subsidiary of Alibaba. As of September 2022, this CBDC was the most commonly used CBDC per capita, with transactions amounting to the over 100 billion yuan (US$14 billion) in the 2 years since its debut.

2.2.3. eNaira

Due to the widespread adoption of cryptocurrencies, Nigeria banned decentralized finance (DeFi) banking nationwide. Four months later, the government declared the issuance of a centralized digital token with a circulating supply of 500 million and a value of US$1.21 million. Despite this move, Bloomberg reports that merely 0.5 % of the country's population of 211 million people possess an eNaira digital wallet.

2.2.4. e-Krona

The impetus behind Sweden's move to introduce an authorized digital currency was the declining reliance on cash by its populace. The Swedish central bank aspires to achieve a market value of US$5000 per e-krona and for 65 % of all transactions in the country to be conducted using this currency in 2022.

2.2.5. JamDex

The Jamaican Senate recently passed legislation to classify virtual tokens as legal currency, alongside paper bills and coins. JamDex, a digital token, was introduced as an alternative to fiat money in the cash-dependent economy of the Caribbean Island nation with the intention of making the equivalent of banking services available to the unbanked population.

2.3. The need for CBDCs

In the event of a scarcity of traditional cash currency, a CBDC will guarantee that a country's people have access to legal tender (Ward and Rochemont, 2019). As more people turn to cards, apps, and contactless payments, the use of cash has decreased. In rare instances, a central bank may choose to exclude cash from the payment system due to its negative impacts, such as illegal trade, money laundering, and tax fraud, which can be difficult to trace when cash is used for payment. Additionally, cash payments pose a higher

Table 1
The Key Literature on CBDCs.

Author	Date	Title
The European Central Bank	2015	"Virtual currency schemes–a further analysis."
The Bank of England	2016	"Central bank-issued digital currencies."
Blog et al.	2017	"Bank of Canada White Paper on Creating Digital Currency - FinTech - Canada."
Gnan and Masciandaro (2018)	2018	"Do we need a central bank digital currency?"
Kumhof and Noone	2018	"Central Bank Digital Currencies—Design Principles and Balance Sheet Implications."
Masciandaro	2018	"Central Bank digital cash and cryptocurrencies: insights from a new Baumol–Friedman demand for money."
Meaning et al. (2018)	2018	"Broadening narrow money: monetary policy with a central bank digital currency."
Wadsworth, A.	2018	"The pros and cons of issuing a central bank digital currency."
De Lis and Sebastian	2019	"Central Bank Digital Currencies and Distributed Ledger Technology."
Fiedler et al.	2019	"The Impact of Digitalization on the Monetary System."
Ward and Rochemont	2019	"Understanding central bank digital currencies (CBDC)."
Bank for International Settlements (2021)	2021	"Central digital currencies for cross-border payments. Report to the G20."
Chucherd et al. (2021)	2021	"Monetary and Financial Perspectives on Retail CBDC in the Thai Context."
Cunha et al. (2021)	2021	"From Bitcoin to central bank digital currencies: Making sense of the digital money revolution."
Fernández et al.	2021	"Central banks' monetary policy in the face of the COVID-19 economic crisis: Monetary stimulus and the emergence of CBDCs."
Fernández-Villaverde at al.	2021	"Central bank digital currency: Central banking for all?"
Náñez Alonso et al.	2021	"Central banks digital currency: Detection of optimal countries for the implementation of a CBDC and the implication for payment industry open innovation."
Allen et al.	2022	"Intech, cryptocurrencies, and CBDC: Financial structural transformation in China."
Becher	2022	"What is a CBDC?"
Bhaskar et al.	2022	"Central bank digital currencies: Agendas for future research."
Chohan	2022	"Central Bank Digital Currencies (CBDCs)."
Keister and Monnet	2022	"Central bank digital currency: Stability and information."
Morgan	2022	"Systemic stablecoin and the defensive case for Central Bank Digital Currency: A critique of the Bank of England's framing."
Mzoughi et al.	2022	"The Bitcoin market reaction to the launch of central bank digital currencies."
Wang et al.	2022	"The effects of central bank digital currencies news on financial markets."
Zhang and Huang	2022	"Blockchain and central bank digital currency."

security risk as they leave no record of the transaction. In the future, governments may consider phasing out cash to reduce crime and increase tax revenues. Furthermore, the introduction of CBDC and bank notes could increase the amount of money in circulation, leading to increased seigniorage (Wadsworth, 2018; Blog et al., 2017).

CBDC is able to ensure efficient and secure payments for large amounts in retail environments, particularly at point-of-sale terminals, online, and for P2P transactions (Ward and Rochemont, 2019). Ward and Rochemont (2019) contend that CBDCs may speed up settlements, allow for shorter settlement hours in wholesale and interbank transactions, and help to eliminate low-value coins by offering electronic change.

In a cashless society, all financial transactions would be conducted digitally. While there are no current plans to eliminate cash, it appears that many industrialized nations are transitioning away from a cash-based culture as digital transactions increase and the use of ATMs decreases. Adrian and Mancini-Griffoli (2021) suggested that a digital currency controlled by the government and backed by a central bank could act as a dependable substitute for physical currency in such circumstances.

If private e-money becomes more popular than fiat money issued by central banks, the potential advantages of having a widely accessible CBDC may be restricted. The profit-driven goals of private e-money providers are incompatible with the social welfare function of fiat currency. If private e-money were to dominate the economy, it could result in a loss of the social welfare benefits provided by the government through fiat currency. This could disproportionately impact those who rely on government aid such as welfare payments, as they may have less access to the widely accepted and privately used e-money than the general population (Fiedler et al., 2019).

Research on CBDCs has gained importance and has been increasing. Table 1 presents some of the key literature on CBDCs published between 2015 and 2022.

2.4. CBDCs and cryptocurrencies

There is a paucity of research to predict the outcomes and effects of CBDCs and the various dimensions of a digital economy. Several studies analyze the implementation of CBDCs, while others portray the aftermath of CBDCs and possible ways to tackle the risks and instability that they may create (Masciandaro, 2018; Fernández-Villaverde et al., 2021; Allen et al., 2022; Keister and Monnet, 2022). In addition, some studies examine the potential effects of CBDCs on large payments and on financial market liquidity (Panetta, 2018). Náñez Alonso et al. (2021) determined that retail CBDCs would assist in meeting the needs of households. Overall, there are few studies on the link between CBDCs and financial markets, and on the link between CBDCs and crypto markets in particular.

There has been an improvement in the overall landscape of research on cryptocurrencies and CBDCs. Researchers have extended their studies since the creation of cryptocurrencies beyond the realm of investment assets. For instance, they have examined the predictability of "financial return assets" in the investment literature (Golez and Koudijs, 2018), which includes forecasting the value of cryptocurrency returns based on stocks (Fama and French, 1988; Campbell and Shiller, 1988; Van Binsbergen and Koijen, 2010). Some studies have employed computational and forecasting methods to examine digital currencies. Liu and Tsyvinski (2021) conducted an extensive analysis of the risk–reward profiles of various cryptocurrencies. According to Malladi et al. (2019), while the returns of stock markets and gold do not have a noteworthy causal influence on Bitcoin returns, Ripple returns do have a notable causal influence on Bitcoin returns. However, there is limited research on predictors of the value of digital currencies, and, as a result, only a small number of predictors have been identified.

Studies have investigated the determinants of Bitcoin returns, although Van Wijk (2013) stated that most of the studies on Bitcoin pricing are associated with the American economy. Ciaian et al. (2016) investigated the effect of various macroeconomic factors, such as the Dow Jones index, oil prices, and the exchange rate on Bitcoin prices, and revealed that these factors influence Bitcoin prices in both short-term as well as long-term. The crypto market has experienced a drastic change in its evolutionary phase. Basic information about Bitcoin, which is available on Wikipedia or social media, significantly influenced Bitcoin prices in the early days but not later on, when awareness about crypto became widespread (Ciaian et al., 2016). The demand and supply factors (evaluated in terms of the size of the Bitcoin economy and the number of Bitcoins in circulation, respectively), however, are important determinants of Bitcoin prices (Ciaian et al., 2016). Bitcoin prices are also heavily influenced by information. For example, positive news significantly increases Bitcoin returns, whereas Bitcoin returns are significantly impacted negatively by bad news (Feng et al., 2018). A study showed that Bitcoin's volatility and trading volume significantly determined the amount of next-day attention that Bitcoin received on Google (Urquhart, 2018). Another study showed that social media sentiment is significantly linked to Bitcoin prices: Bitcoin prices go up in reaction to bullish posts on Twitter and other social media (Mai et al., 2018). There is also a significant connection between cultural factors and the adoption of Bitcoin. For instance, a study found a significantly positive effect of individualism on the use of Bitcoin (Foley et al., 2022). The literature is still underdeveloped not only because of the paucity of research on the issue but also because the phenomenon itself is underdeveloped.

Bouri et al. (2017) used daily and weekly returns data in a dynamic conditional correlation (DCC) model to demonstrate that Bitcoin may serve as an effective diversifier in most situations. A recent fluctuation in Bitcoin prices is a consequence of market emotion, which has been linked to a strong "memory" (Cheah and Fry, 2015; Katsiampa, 2017). Based on these studies, one moderately important driver of cryptocurrency prices is the "memory" of Bitcoin price shocks. Bitcoin can be an appropriate instrument for risk aversion, as it can shield investors from negative market shocks (Dyhrberg, 2016). Cheah and Fry (2015) defined cross-market Bitcoin pricing as a partially cointegrated vector autoregressive (VAR) system with dynamically dependent long-memory 95 procedures. They found evidence of long-term memory in both single- and five-market systems, showing that they exhibited heterogeneous informational inefficiency and a cointegration connection with slow shock arrangement.

As for CBDCs, there are considerations about whether they should be blockchain-based or not, as there are challenges to predicating

a CBDC on the blockchain (Zhang and Huang, 2022). While CBDCs are certainly a reaction of governments to the rise of digital currencies, debates over CBDCs may also influence the behavior of crypto investors (Scharnowski, 2022). Some regard CBDCs as a potential threat to the cryptocurrency market. Wang et al. (2022a) found that there is a strong positive correlation between the uncertainty around the implementation of CBDCs and volatility in the cryptocurrency market. They also examined the impact of CBDC indices on financial market volatility and discovered that there is a significantly negative correlation between CBDC indices and the volatility of the USEPU index, the FTSE All-World index, and the MSCI World Bank index. In addition, they hypothesized that the greater the risk in CBDC indices risk, the higher is the volatility exhibited by financial variables. If one considers blockchain-based currencies as the future of the payment system, then retail CBDCs may have the potential to crowd them out, as the development of CBDCs has profound implications for monetary and payment systems (Bhaskar et al., 2022). Yet, others consider CBDCs an important addition to the digital currency ecosystem, that will result in cryptocurrencies gaining strength. A recent study found that CBDCs are not in competition with decentralized cryptocurrencies but an important entry point to introducing versatility to digital monetary mechanisms (Scharnowski, 2022). Scharnowski (2022) determined that positive discussions about CBDCs are taken as positive news by crypto traders, thereby sending a positive signal to the crypto market. Therefore, in our setting, we hypothesize the following:

Hypothesis. : Major announcements and events related to CBDC have a significant influence on Bitcoin returns.

The conceptual framework is illustrated in Fig. 1. This study investigates how Bitcoin returns are impacted by CBDC indices, specifically the CBDC uncertainty index and the CBDC attention index, which are used as measures of CBDC-related news. This paper hypothesizes that the amount of CBDC news is significantly linked to Bitcoin returns while considering the effect of various control variables.

This study explores the impact of news related to CBDCs on Bitcoin returns as well as the correlations between various cryptocurrencies. The emergence of CBDCs as an alternative to existing payment methods has the potential to influence Bitcoin returns, as CBDC news can affect investor sentiment and market expectations. Comprehending the effect of CBDC news on Bitcoin returns can be valuable for investors, regulators, and other market players. Additionally, studying the correlation between cryptocurrencies is crucial, as it can assist in shaping investment strategies and risk management practices. Econometric models, including the DCC-GARCH model, can aid in identifying the factors that impact the correlation between cryptocurrencies, such as CBDC news and other market-related variables.

Overall, a conceptual framework that incorporates CBDC news, Bitcoin returns, and the correlation between cryptocurrencies will prove useful for studying the complex and rapidly evolving landscape of digital currencies and the financial markets.

3. Methodology

This study collected data from CoinMarketCap on the three largest cryptocurrencies, which had a collective market value exceeding £ 1 billion at the time of the study. The data collection period was between August 1, 2017 and April 1, 2022, and data collection was performed on a weekly basis. The chosen cryptocurrencies were Bitcoin, Ethereum, and Binance Coin (Binance), as they have the highest market capitalization. Other cryptocurrencies, such as Tether and XRP, were not included in the sample, as they have such a low market capitalization that they were considered irrelevant to this study. Therefore, the model linking returns to CBDC index is shown in Eq. (1):

$$\text{BTC return}t = \alpha + \beta 1\text{x CBDC Index t} + \beta 2\text{x ETH return t} + \beta 3\text{x BNB return t} + \varepsilon \quad (1)$$

whereα: represents the intercept;β: a measure of the coefficients of predictors;*BTC*: Bitcoin returns;*BNB*: Binance returns;*ETH*: Ethereum returns; andε: disturbance term.

Wang et al. (2022a) developed two induces for CBDCs to track trends and volatilities in CBDCs, namely CBDC uncertainty index and CBDC attention index. The indices were constructued by using 663 million news items gathered from the Lexis Nexis News & Business starting from January 2015. The indices show distinct movements around major CBDC announcements, currency flash-news, policy debates, and significant events related to digital currencies. Uncertainty indices are used in the currency market to capture the uncertainties related to prices, policy (Lucey et. al., 2022). Positive news items policy updates are negatively linked to CBDC the historical

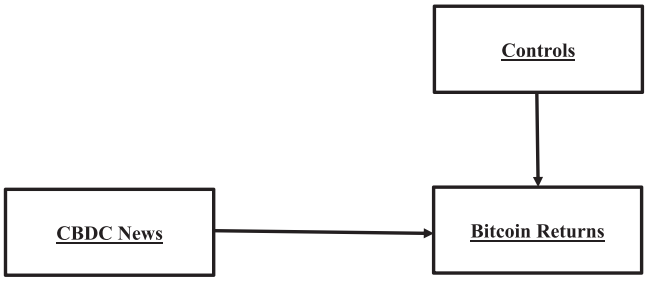


Fig. 1. Conceptual Framework.

decomposition results of CBDC uncertainty index, indicating a reduction in uncertainty surrounding the introduction of CBDC. Attention index is used to measure the attention garnered by a currency in media, particularly digital media (Wang et al., 2022b).

The method used to determine the returns for the selected cryptocurrencies is based on the natural logarithm of the arithmetic return. This method is appropriate for analyzing time series returns because it considers statistical properties such as stationarity and ergodicity, as noted by Bortoluzzo et al. (2010). The methodology for calculating the cryptocurrency returns is similar to that of Smales (2022) and can be expressed as follows:

$$Ri = \ln(Pt/Pt-1) = \ln(Pt)\text{–}\ln(Pt-1) \tag{2}$$

To determine the return of a cryptocurrency, the arithmetic return is computed by subtracting the daily closing price of the cryptocurrency in period $t-1$ $(Pt-1)$ from its daily closing price in period t (Pt). This arithmetic return is then transformed using the natural logarithm to calculate the cryptocurrency's return.

3.1. DCC-GARCH model specification

To apply a generalized autoregressive conditional heteroscedasticity (GARCH) model, it is necessary for the time series data to display both stationarity and ARCH effects. According to Table 4 all of the time series variables exhibit non-stationarity in relation to the continuously compounded returns.

The DCC model, which was suggested by Engle (2002), makes it possible to determine the time-varying correlation between a number of distinct variables. Estimation of the DCCs has been performed in a great number of studies using multivariate GARCH-DCC models (Ciner et al., 2013).

If there is a serial correlation in either the returns or residuals, it can be identified by incorporating an autoregressive moving average (ARMA) (p, q) model into the DCC-GARCH model. The ARMA-DCC-GARCH model is characterized as follows:

$$R_t = diag\{Q_t\}^{-1/2} Q_t diag\{Q_t\}^{-1/2} \tag{3}$$

$$Q_t = \Omega + \alpha\varepsilon_{t-1}\varepsilon_{t-1}^{'} + \beta Q_{t-1}, \Omega = R'(1-\alpha-\beta) \tag{4}$$

$$\left(1 - \Phi_1 B - I - \Phi_P B^P\right) Y_t = c + (1 + \Theta_1 I \ldots + \Theta_q B^q)\eta_t, \eta_t | F_{t-1} \sim t(0, D_t R_t D_t, \upsilon) \tag{5}$$

$$D_t^2 = diag \quad \{H_1\}, H_t = V_{t-1}(\eta_t) \tag{6}$$

$$H_{i,t} = \omega_i + \alpha_i \eta_{i,t-1}^2 + \beta_i H_{i,t-1} \tag{7}$$

$$\varepsilon_t = D_t^{-1}\eta_t \tag{8}$$

In the ARMA-DCC-GARCH model, the multiple time series of returns is represented by Y_t, while the vector of conditional means of returns is represented by Q_t. The conditional variance for the ith-correlated returns (here, I ranges from 1 to N) is represented by $H_{i,t}$. The time-varying variance is denoted by $V_{t-1}(\eta_t)$, and the conditional covariance matrix of the disturbance term is represented by η_t. Symbol c represents the vector of constants, while the parameters of the ARMA (p, q) model are denoted by Φ and Θ. For the i-th returns, the parameters of the conditional variance equation are represented by ωi, αi, and ßi, while the parameters of the conditional correlation equation are represented by α and ß. The number of degrees of freedom in the t-distribution is represented by $\nu > 2$, and the unconditional covariance matrix is included. To detect the serial correlation in returns or residuals, it is possible to add the ARMA (p, q) model to the DCC-GARCH model.

The estimates of the DCC-GARCH model can be computed by applying the maximum likelihood technique, which involves a two-stage approach (Engle, 2002, 2009). During the first stage, the calculation of the "conditional variance equations" and the "means" is carried out. During the second stage, the estimation of the "conditional correlation equation" is performed.

The cross-account correlation test is commonly used to compare two distinct securities in different market conditions or trading periods: one in stable conditions and the other volatile conditions. An increase in the correlation estimates during turbulence suggests the existence of contagion or ripple effects (King and Wadhwani, 1990; Lee and Kim, 1993; Rengasamy, 2012). Nonetheless, this method has been subject to criticism for failing to account for possible heteroskedasticity. In response to this issue, the implementation of Bollerslev's GARCH model (1986) has been suggested (Forbes and Rigobon, 2001; Bouaziz et al., 2012).

4. Results

4.1. Descriptive statistics

Descriptive statistics for this study are shown in Table 2.

Table 2 provides summary statistics for the volatility of Bitcoin, Binance, and Ethereum between August 1, 2017 and April 1, 2022. The table shows that Bitcoin prices are very volatile during this period, with a minimum price of £2061,97 on August 1, 2017 and a maximum price of £ 47,161 on November 12, 2021. On August 1, 2017, the minimum prices of Ethereum and Binancedynam were £71.63 and £ 0.08, respectively. By November 12, 2021, the Binance price had increased from £ 0.08 to £ 470.5, while Ethereum's

price had increased by £3458.1. According to Brown (2006), the kurtosis value should be between –10 to + 10, while an acceptable value of skewness is between –3 and + 3. The skewness and kurtosis values are greater than 1 for all of the variables, which indicates that the distribution is significantly skewed. The distribution is also peaked, as the kurtosis is higher than 1. The skewness and kurtosis values are acceptable.

Previous research on cryptocurrencies has also investigated the volatility and price fluctuations in different cryptocurrencies. Cheah and Fry's (2015) study analyzed Bitcoin's price and trading volume and discovered that Bitcoin prices were extremely volatile from 2011 to 2013. Katsiampa (2017) found that Bitcoin had a higher market value and more trading activity than Ripple and Litecoin. Thus, the findings of the present study are consistent with some of the previous research in the field of cryptocurrencies and can help guide future research and analysis in this area.

Fig. 2 demonstrates the evolution of Bitcoin returns from January 1, 2018 to April 1, 2022. The graph displays significant variations or fluctuations in the levels during periods of turmoil, particularly during the COVID-19 pandemic. There is a clustering of volatility Bitcoin returns, which implies that periods with either high or low levels of volatility are likely to be succeeded by a period of a similar level of volatility. This pattern of volatility clustering, also known as heteroskedasticity, is a common characteristic of Bitcoin markets. To accurately describe the behavior of volatility over time, as well as during periods of stability and turbulence, models such as the ARCH/GARCH family are commonly used.

Table 3 displays the matrix of correlations between the independent variables: Ethereum returns, Binance returns, CBDC uncertainty, and CBDC attention. According to the table, there is a significant positive correlation at the 5 % level between Binance and Ethereum returns. The correlation coefficient between the two variables is 0.46. This indicates that the major currencies move in synchronization. The CBDC uncertainty index and the CBDC attention index are highly correlated, with a statistically significant correlation coefficient of approximately 0.57. The largest correlation in the table is between CBDC attention and Binance Coin, with a correlation coefficient of 0.58. Overall, the table suggests that multicollinearity in the data is not a concern and that the independent variables are not highly correlated with each other.

Other researchers have also examined the correlations between various cryptocurrencies. Cheah and Fry (2015) found that the value and volume of transactional activity of Bitcoin were positively correlated with those of Litecoin and Ripple. Katsiampa (2017) demonstrated that Bitcoin displayed a positive correlation with Litecoin and Ripple in terms of transaction volume and the total value of Bitcoin in circulation. Katsiampa (2017), however, showed that Bitcoin was negatively correlated with the U.S. dollar. A separate study found that Bitcoin was positively correlated with gold, the S&P 500, and other cryptocurrencies (Bouri et al., 2017).

There is limited empirical research on the correlation between CBDCs and investor attention. However, some papers have speculated that the introduction of CBDCs could lead to increased investor attention and interest in digital currencies more broadly. CBDCs exert a notable influence on the virtual asset market (Mzoughi et al., 2022). The results presented in Table 3 align with previous research on the correlations between cryptocurrencies. The positive correlation between Ethereum return and Binance returns is consistent with the idea that the major cryptocurrencies demonstrate a tendency to progress in tandem. The strong correlation between CBDCs and investor attention is also consistent with the idea that CBDCs are a major factor influencing the cryptocurrency market.

Table 4 reports the findings of the unit root tests for the factors used in this study. For each factor, the table presents the results of the Augmented Dickey–Fuller (ADF) test. The results imply that the variables possess time series that are non-stationary in nature, and at a significance level of 5% the null hypothesis of a unit root for all variables is rejected. In the event that the p-value exceeds 0.05, the ADF unit root test would need to be followed by the first difference. Nonetheless, the rejection of the null hypothesis at a 5 % significance level implies that additional analysis is necessary, as all of the variables appear to be non-stationary.

The purpose of the unit root test displayed in Table 4 is to assess whether the time series data for each variable exhibit stationarity. This is in line with prior studies on cryptocurrency returns. Katsiampa (2017) used the ADF test to examine the stationarity of Bitcoin, Litecoin, and Ripple returns and found that all three cryptocurrencies had non-stationary returns. Feng et al. (2018) found no stationarity in Bitcoin returns, as determined by the Phillips–Perron test. The unit root test results, presented in Table 4, align with prior research on cryptocurrency returns, suggesting that the time series data for these variables are non-stationary.

The outcome of the DCC-GARCH (1,d,1) model is shown in Table 5. The model investigates the dynamic adjustments of the conditional correlation within the framework of the multivariate DCC model using the GARCH model (1,d,1). The table presents the estimation results for the coefficients and t-prob of the variables under investigation. The the GARCH estimates indicate that CBDC uncertainty index, Ethereum returns, and Binance returns impact Bitcoin returns at the 10 % significance level.

The results of these statistical tests show that there is a strong link between the CBDC uncertainty index and Bitcoin returns. This finding supports our hypothesis. Additionally, when Ethereum and Binance returns increase, Bitcoin returns also increase. As the parameters of the model estimated using the maximum likelihood method are statistically significant. The t distribution is strongly favored, as the results indicate that it is highly significant.

Table 2
Descriptive Statistics.

Variables	Min (£)	Max (£)	Mean (£)	Std. Deviation	Skewness	Kurtosis
Bitcoin Price	2061.97	47,161.19	913763.38	12772.93	1.19	0.08
Ethereum Price	71.63	3458.10	730,33	884.51	1.50	0.97
Binance Price	0.08	470.50	83.68	132.71	1.53	0.82
CBDC Uncertainty Index	99.31	106.15	100.28	1.42	1.64	2.34
CBDC Attention Index	99.42	106.15	100.35	1.64	1.56	1.04

Fig. 2. Return Behavior Over Time.

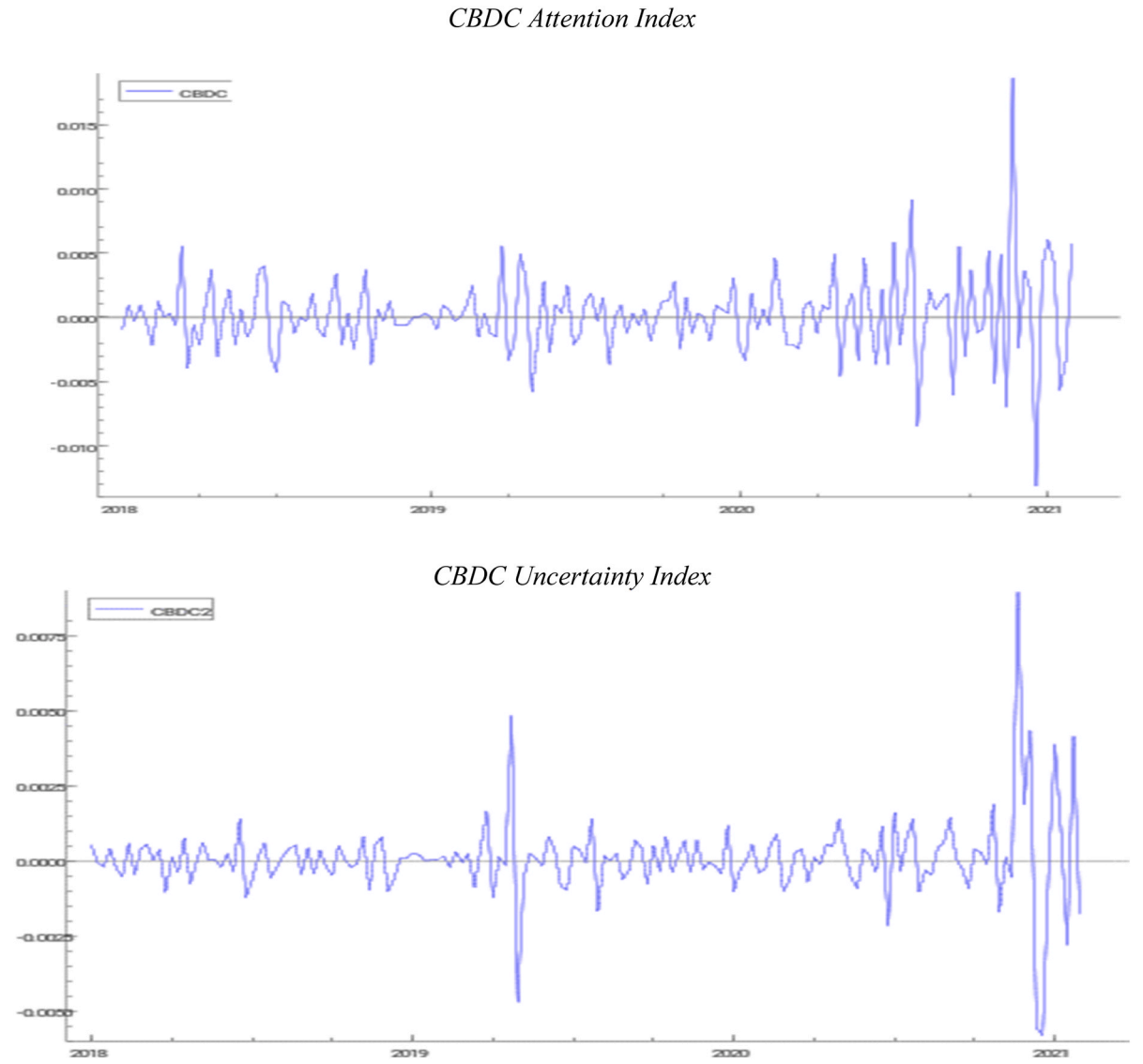


Fig. 2. (*continued*).

Prior studies on the interrelationships between cryptocurrencies have employed multivariate models to explore the dynamic adjustments of the conditional correlation between cryptocurrencies. Zhang and Huang (2022) applied the DCC-GARCH model to examine the links between the blockchain and CBDCs. They ascertained that blockchain technology has a positive effect on the development of CBDCs. Similarly, Yermack (2017) utilized the same model to investigate how corporate governance and blockchain are associated and found that blockchain has the potential to enhance corporate governance.

A separate study employed a GARCH model and observed that Bitcoin, Litecoin, and Ripple returns exhibit high levels of volatility (Katsiampa, 2017). This result was corroborated by Feng et al. (2018), who employed a similar GARCH model and identified a significant effect of informed trading on the volatility of Bitcoin returns.

In summary, the results presented in Tables 4 and 5 yield valuable insights into the dynamics of the variables under investigation. Table 4 indicates that the variables are not stationary, which requires further analysis. Table 5 suggests a significant correlation between the CBDC uncertainty index and Bitcoin returns and a positive impact of Ethereum and Binance returns on Bitcoin returns. The incorporation of the DCC-GARCH model enhances the robustness of this study's findings.

Fig. 3 illustrates the fluctuations in dynamic conditional correlations throughout the entire sampling timeframe (January 2018 through May 2022). The chart depicts the changing correlation over time between the returns on Bitcoin and other variables, such as Ethereum, Binance returns, the CBDC uncertainty index, and the CBDC attention index. The graphical representation showcases the dynamic nature of the positive correlation between Bitcoin and Ethereum returns, which fluctuates over time.

Returns on Bitcoin and Binance are also positively correlated and vary over time, with some periods demonstrating a higher

Table 3
Matrix of Total Correlations.

Variable	Ethereum_return	Binance Coin_return	CBDC Uncertainty	CBDC Attention
Ethereum_return	1			
Binance Coin_return	0.4597 **	1		
CBDC Uncertainty	0.5488 **	0.5311 **	1	
CBDC Attention	0.5541 ***	0.5821	0.5711 ***	1

Note: * , **, and *** denote a 1 %, 5 %, and 10 % level of significance.

Table 4
Unit Root Test Results.

Variables	ADF Test
Bitcoin return	–14.0117 ***
Ethereum_return	–7.4435 ***
Binance Coin_return	–12.8920 ***
CBDC uncertainty	–5.0206 ***
CBDC attention	–6.5217 ***

Note: *, **, and *** denote a 1 %, 5 %, and 10 % level of significance.

correlation than others. The graph also shows that Bitcoin returns and the CBDC uncertainty index are negatively correlated: as CBDC uncertainty increases, Bitcoin returns tend to decrease. Finally, the graph shows that returns on Bitcoin are positively correlated with the CBDC attention index: Bitcoin returns tend to increase as CBDC attention increases.

Previous research on cryptocurrency returns has also used DCC models to analyze the correlation between cryptocurrencies. Bouri et al. (2017) investigated how Bitcoin is associated with traditional market instruments and found that the correlation between Bitcoin and traditional financial assets was negligible. This indicates that investors consider Bitcoin as a means of diversification. However, Corbet et al. (2019) discovered a weak correlation between Bitcoin and gold, suggesting that Bitcoin could serve as a defense against inflationary pressures. According to Mzoughi et al. (2022), the introduction of CBDCs has a noteworthy effect on Bitcoin, indicating that the launch of CBDCs results in improvements in the decentralized assets sector.

5. Conclusion

This study's findings reveal that CBDC news significantly influences Bitcoin returns, with positive news leading to higher returns. Additionally, a positive and statistically significant relationship exists between Bitcoin returns and the returns of other digital currencies (specifically, Ethereum and Binance). These findings provide valuable insights into the interrelationships between CBDCs, the major cryptocurrencies, and Bitcoin, underscoring the importance of monitoring CBDC news for cryptocurrency investors.

The results confirm the assertion that an improvement in CBDCs is taken as a positive development by Bitcoin investors. The rationale is that the market still has a long way to go to capture the great potential demand for digital currency, so any development by central banks in this direction is seen as a positive development toward creating an overall stable ecosystem.

This paper contributes to the growing body of research on the impact of CBDC development on the cryptocurrency market by providing new insights and policy recommendations. Notably, the findings may inform the effective regulation and risk management strategies of investors. The results underscore the importance of careful consideration by policymakers and market participants of the potential benefits and risks of virtual currencies for the global financial architecture.

To properly oversee the banking sector in the age of disruptive digital technologies in the financial landscape, authorities must first establish an effective regulatory system. By doing so, they can create a strong financial sector and reduce the risk of contagion. Second,

Table 5
Estimation Results for the DCC-GARCH (1,d,1) Model.

	Bitcoin-Coeff	Ethereum t-prob	Bitcoin Coeff	Binance Coin t-prob	Bitcoin Coeff	CBDC Uncertainty t-prob	Bitcoin Coeff	CBDC Attention t-prob
Panel A:								
Rho	0.0536	0.0011	0.0202	0.0373	0.1253	0.0003	0.0838	0.0493
Alpha	0.0001	0.0693	0.022	0.03743	0.0168	0.0191	0.0063	0.0404
Beta	0.0002	0	0.1178	0.0815	0.9704	0	0.9915	0.0000
Df	8.8138	0	6.9183	0	8.6808	0	8.7677	0.0000
Panel B:								
***Hosking* (20)**	536.214	[0.0000]	95.1106	[0.2991]	103.798	[0.0431]	247.378	[0.0000]
***Hosking*^{2}(20)**	852.251	[0.0000]	167.516	[0.0000]	355.795	[0.0000]	546.957	[0.0000]
***Li–Mcleod* (20)**	736.067	[0.0000]	95.169	[0.2976]	201.808	[0.0430]	347.379	[0.0000]
***Li–Mcleod*^{2} (20)**	551.334	[0.0000]	164.479	[0.0000]	555.091	[0.0000]	346.162	[0.0000]

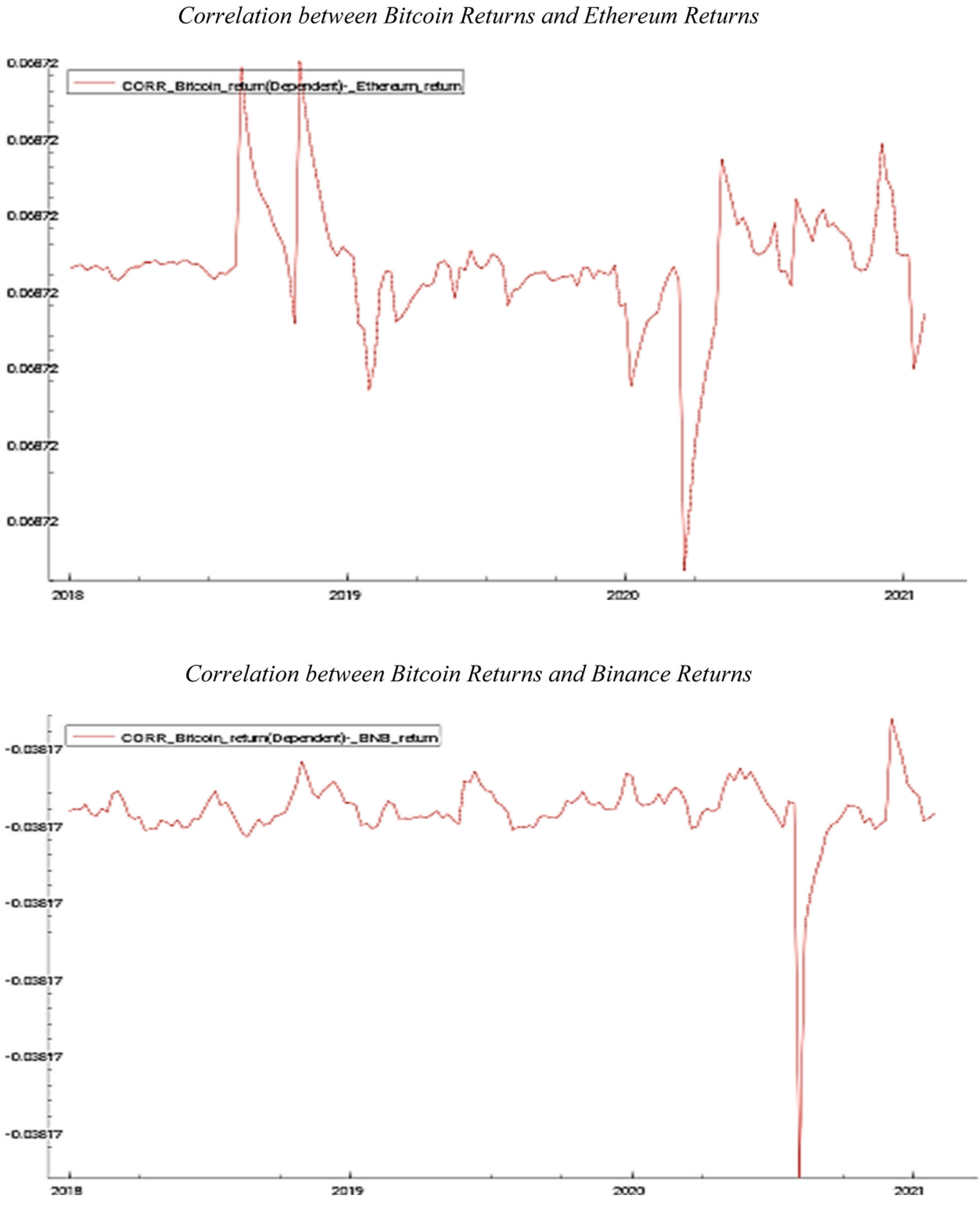
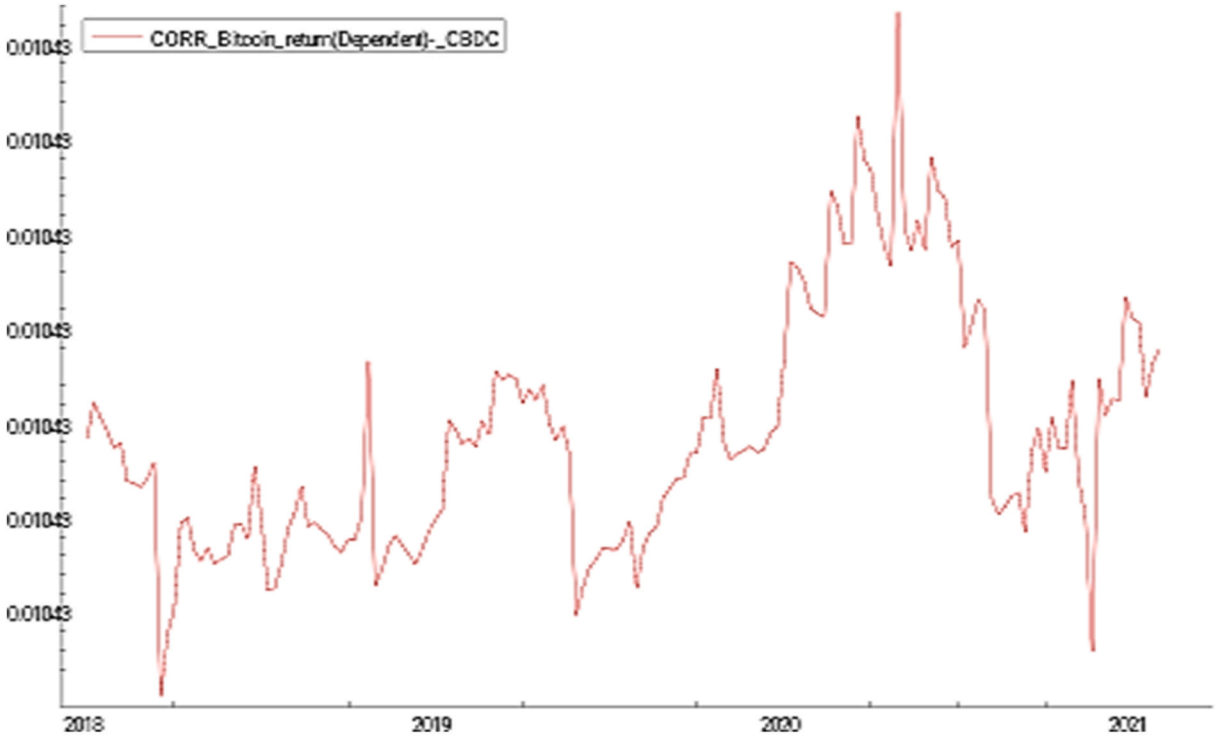


Fig. 3. Dynamic conditional correlations during the full study period.

using current risk management approaches, regulators must periodically study and track the spread of financial contagion. Stress tests and machine-learning methods may be useful in this situation. The impact on other financial sectors, including the equity and currency markets, should also be carefully examined. In addition, policymakers should consider the potential risks associated with the use of

Correlation between Bitcoin Returns and the CBDC Attention Index



Correlation between Bitcoin Returns and the CBDC Uncertainty Index

Fig. 3. (*continued*).

cryptocurrencies and CBDCs, such as money laundering and terrorist financing. We also invite attention to the potential impact of CBDCs on the cryptocurrency market, particularly the potential risks and instability they could create in the financial markets.

The present research employs the DCC-GARCH model for predicting Bitcoin returns, which enables superior forecasting of Bitcoin prices. This statistical price forecasting model has been validated using real-world data for Bitcoin, Binance, Ethereum, and the CBDC indices. This model may be used as an alternative model when traditional price forecasting models fail, especially in times of high price volatility levels. In addition, the model may be useful for investors or companies, as it can be applied to create a portfolio. In the future, it will be helpful to further examine the behavior of cryptocurrencies by incorporating additional digital coins such as XRP, Dogecoin, Cardano, and Stellar. Further investigation will be useful in maintaining a perspective on the different purposes these coins serve and the different technologies on which they are founded. Certainly, an extension of the time frame may also improve the generalizability of the framework.

There are also other areas of research that require scholarly attention. For instance, future research could investigate the determinants of the adoption and use of cryptocurrencies in the context of CBDCs and existing cryptocurrencies, the potential of blockchain technology to increase market liquidity, and the impact of cultural factors on the adoption of digital currencies. Moreover, future research could explore the potential of digital currencies to address other socioeconomic problems such as income inequality and financial inclusion.

This study also has some limitations. For example, the data used in this research were limited to revealing the relationship between the variables not only in terms of the period covered but also in terms of the currencies included. Binance and Ethereum were taken as the major cryptocurrencies at the time that this research was conducted. The results of the research may be affected when additional data and other cryptocurrencies are included in the model. Additionally, some studies use different methodologies, making it difficult to compare findings. The determinants of cryptocurrency development comprise a growing field of research that requires further attention. Future research should address these limitations using larger and more diverse data sets and more consistent methodologies, which will eventually lead to greater agreement among researchers.

CRediT authorship contribution statement

Dr. Isik Akin (Literature, analysis and write-up). Dr. Affan Hameed (data management, discussion and interpretation). Dr. Kaouthar Chebbi (methodology). Dr. Muhammad Zubair Khan (analysis and literature review). Hakan Satiroglu (data management, formatting, and write-up).

Data Availability

Data will be made available on request.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ribaf.2023.102060.

References

Abu-Bakar, M.M., 2018. Shariah analysis of bitcoin, cryptocurrency, and blockchain. Shariah Anal. Light Fatwas Scholars' Opin. Link [Accessed: 25.01.2023].
Adrian, T., Mancini-Griffoli, T., 2021. The rise of digital money. Int. Monet. Fund. Annu. Rev. Financ. Econ. 13 (1), 57–77. Link [Accessed: 15/12/2022].
Allen, F., Gu, X., Jagtiani, J., 2022. Fintech, cryptocurrencies, and CBDC: financial structural transformation in China. J. Int. Money Financ. 124, 102625. Link [Accessed: 15.12.2022].
Bank of England (2016). Central Bank-issued digital currencies. Link [Access 27.12.2022].
Chohan, U.W. (2022). Central Bank digital currencies (CBDCs). *Available at SSRN.* Link: [Access 15.03.2023].
Chucherd, T., Mek-yong, C., Nookhwun, N., Nuntnarumit, P., Piyakarnchana, N., Suwanik, S., 2021. Monetary and financial perspectives on retail CBDC in the Thai context, 152. Puey Ungphakorn Inst. Econ. Res. Link [Access 12.12.2022].
Ciaian, P., Rajcaniova, M., Kancs, D.A., 2016. The economics of BitCoin price formation. Appl. Econ. 48 (19), 1799–1815. Link [Access 06.04.2021].
Ciner, C., Gurdgiev, C., Lucey, B.M., 2013. Hedges and safe havens: an examination of stocks, bonds, gold, oil and exchange rates International review of financial. Analysis 29, 202–211. Link [Access 07.04.2021].
Clemons, E.K., Row, M.C., 1992. Information technology and industrial cooperation: the changing economics of coordination and ownership. J. Manag. Inf. Syst. 9 (2), 9–28. https://doi.org/10.1080/07421222.1992.11517956.
Corbet, S., Lucey, B., Urquhart, A., Yarovaya, L., 2019. Cryptocurrencies as a financial asset: a systematic analysis. Int. Rev. Financial Anal. 62, 182–199. Link: [Access 23.03.2023].
Cunha, P.R., Melo, P., Sebastião, H., 2021. From bitcoin to central bank digital currencies: making sense of the digital money revolution. Future Internet 13 (7), 165. Link [Access 10.04.2021].
De Andrés, P., Arroyo, D., Correia, R., Rezola, A., 2022. Challenges of the market for initial coin offerings. Int. Rev. Financ. Analy. 79, 101966. Link [Access 25.01.2023].
Engle, R., 2002. Dynamic conditional correlation: a simple class of multivariate generalized autoregressive conditional heteroskedasticity models. J. Bus. Econ. Stat. 20 (3), 339–350. Link [Access 03.04.2021].
European Central Bank, 2015. Virtual currency schemes–a further analysis. Tech. rep. European Central Bank,, Frankfurt am Main, Germany. Link [Access 20.12.2022].
Aste, T. (2016). The fair cost of Bitcoin proof of work. Available at SSRN 2801048. Link [Access 03.04.2021].
Bank for International Settlements (2021). Central digital currencies for cross-border payments. Report to the G20, Basel, July 21. Link [Access 26.12.2022].

Becher, B. (2022). What is a CBDC? Built In. Link [Access 26.12.2022].
Best, J., 2018. Breaking Digital Gridlock. Wiley & Sons,.
Bhaskar, R., Hunjra, A.I., Bansal, S., Pandey, D.K., 2022. Central bank digital currencies: agendas for future research. Res. Int. Bus. Financ. 62, 101737. Link [Access 26.01.2023].
Bjerg, O., 2016. How is bitcoin money? Theory Cult. Soc. 33 (1), 53–72. Link: [Access 24.01.2023].
Blog, C.L., Shauvik, S., Ho, A., 2017. Bank of Canada white paper on creating digital currency – Fintech – Canada. Bank of Canada White Paper on Creating Digital Currency. FinTech, Canada.
Böhme, R., Christin, N., Edelman, B., Moore, T., 2015. Bitcoin: economics, technology, and governance. J. Econ. Perspect. 29 (2), 213–238. Link [Access 18.12.2022].
Bollerslev, T., 1986. Generalized autoregressive conditional heteroskedasticity. J. Econ. 31 (3), 307–327. Link: [Access 29.03.2023].
Bortoluzzo, A.B., Morettin, P.A., Toloi, C.M.C., 2010. Time-varying autoregressive conditional duration model. J. Appl. Stat. 37 (5), 847–864. Link [Access 12.12.2022].
Bouaziz, M.C., Selmi, N., Boujelbene, Y., 2012. Contagion effect of the subprime financial crisis: evidence of DCC multivariate GARCH models European. J. Econ. Financ. Adm. Sci. 44 (1), 66–76. Link [Access 05.01.2023].
Bouri, E., Molnár, P., Azzi, G., Roubaud, D., Hagfors, L.I., 2017. On the hedge and safe haven properties of Bitcoin: is it really more than a diversifier? Financ. Res. Lett. 20, 192–198. Link [Access 15.12.2022].
Brown, T.A., 2006. Confirmatory Factor Analysis for Applied Research. Guilford Press,.
Campbell, J.Y., Shiller, R.J., 1988. The dividend-price ratio and expectations of future dividends and discount factors. Rev. Financ. Stud. 1 (3), 195–228. Link [Access 15.04.2021].
Cheah, E.T., Fry, J., 2015. Speculative bubbles in Bitcoin markets? An empirical investigation into the fundamental value of Bitcoin. Econ. Lett. 130, 32–36. Link [Access 12.04.2021].
De Lis, S.F., and Sebastian, J. (2019). Central Bank digital currencies and distributed ledger technology. Link [access:02.04.2021].
Dyhrberg, A.H. (2016). Bitcoin, gold and the dollar–A GARCH volatility analysis Finance Research Letters, 16, 85–92. Link [Access 03.04.2021].
Echarte Fernández, M.Á., Náñez Alonso, S.L., Jorge-Vázquez, J., and Reier Forradellas, R.F. (2021). Central banks' monetary policy in the face of the COVID-19 economic crisis: Monetary stimulus and the emergence of CBDCs Sustainability, 13(8), 4242. Link [Access 03.04.2021].
Engle, R., 2009. Anticipating Correlations: A New Paradigm for Risk Management. Princeton University Press,. Link [Access 03.04.2021].
Fama, E.F., French, K.R., 1988. Dividend yields and expected stock returns. In: Fama Portfolio, 22. University of Chicago Press, pp. 3–25. Link [Access 18.04.2021].
Feng, W., Wang, Y., Zhang, Z., 2018. Informed trading in the Bitcoin market. Financ. Res. Lett. 26, 63–70. Link [Access 22.01.2023].
Fernández-Villaverde, J., Sanches, D., Schilling, L., Uhlig, H., 2021. Central Bank digital currency: central banking for all. Rev. Econ. Dyn. 41, 225–242. Link [Access 10.04.2021].
Fiedler, S., Gern, K.J., Stolzenburg, U., 2019. The impact of digitalisation on the monetary system. Econ. Comm. Monet. Dialog-. Pap. Link [Access 21.12.2022].
Foley, S., Frijns, B., Garel, A., Roh, T.Y., 2022. Who buys Bitcoin? The cultural determinants of Bitcoin activity? Int. Rev. Financ. Anal. 84, 102385. Link [Accessed: 24.01.2023].
Forbes, K., Rigobon, R., 2001. Measuring contagion: conceptual and empirical issues. International Financial Contagion. Springer,, Boston, MA, pp. 43–66. Link [Access 06/01/2023].
Franco, P., 2014. Understanding Bitcoin. Wiley & Sons,.
Gnan, E., Masciandaro, D., 2018. Do we need central bank digital currency? Economics, technology and institutions. Suerf-The European Money and Finance Forum,, Vienna. Link [Access:11.12.2022].
Golez, B., Koudijs, P., 2018. Four centuries of return predictability. J. Financ. Econ. 127 (2), 248–263. Link [Access 20.04.2021].
Goodman, L.M., 2014. The face behind Bitcoin. Newsweek. Link [Accessed: 15.12.2022], March, 6.
Grinberg, R., 2012. Bitcoin: an innovative alternative digital currency. Hastings Sci. Tech. LJ 4, 159. Link [Access 11.12.2022].
Hendrickson, J.R., Hogan, T.L., Luther, W.J., 2016. The political economy of bitcoin. Econ. Inq. 54 (2), 925–939. Link [Access 01.04.2021].
Jopson, B., 2016. Regulators say bitcoin poses 'financial stability risks'. Financial Times 21. Link [Access 15.12.2022].
Katsiampa, P., 2017. Volatility estimation for Bitcoin: a comparison of GARCH models. Econ. Lett. 158, 3–6. Link [Access 18.04.2021].
Keister, T., Monnet, C., 2022. Central Bank digital currency: stability and information. J. Econ. Dyn. Control 142, 104501. Link [Access 18.04.2021].
Kimani, D., Adams, K., Attah-Boakye, R., Ullah, S., Frecknall-Hughes, J., Kim, J., 2020. Blockchain, business and the fourth Industrial Revolution: Whence, whither, wherefore and how? Technol. Forecast. Soc. Change 161, 120254.
King, M.A., Wadhwani, S., 1990. Transmission of volatility between stock markets. Rev. Financ. Stud. 3 (1), 5–33. Link: [Access 09.01.2023].
Kumhof, M., Noone, C., 2018. Central Bank digital currencies—design principles and balance sheet implications. SSRN Electron. J. *725*. Link [Access 15.12.2022].
Lee, S.B., Kim, K.J., 1993. Does the October 1987 crash strengthen the co-movements among national stock markets? Rev. Financ. Econ. 3 (1), 89–102. Link: [Access 09.01.2023].
Liu, Y., Tsyvinski, A., 2021. Risks and returns of cryptocurrency. Rev. Financ. Stud. 34 (6), 2689–2727. Link [Access 22.04.2021].
Mai, F., Shan, Z., Bai, Q., Wang, Chiang, R.H.L., 2018. How does social media impact bitcoin value? A test of the silent majority hypothesis. Routledge 35 (1), 19–52.
Malladi, R., Dheeriya, P., Martinez, J., 2019. Predicting Bitcoin return and volatility using gold and the stock market. Q. Rev. Bus. Discip. 5 (4), 357–373. Link [Access 22.04.2021].
Masciandaro, D., 2018. Central Bank digital cash and cryptocurrencies: insights from a new Baumol–Friedman demand for money. Aust. Econ. Rev. 51 (4), 540–550. Link [Access 21.04.2021].
Meaning, J., Dyson, B., Barker, J., Clayton, E., 2018. Broadening narrow money: Monetary policy with a central bank digital currency. Link [Access 15.12.2022].
Mikołajewicz-Woźniak, A., Scheibe, A., 2015. Virtual currency schemes–the future of financial services. Foresight 17 (4), 365–377. Link [Access 19.04.2021].
Morgan, J., 2022. Systemic stablecoin and the defensive case for Central Bank Digital Currency: a critique of the Bank of England's framing. Res. Int. Bus. Financ. 62, 101716. Link [Access 17.12.2022].
Mzoughi, H., Benkraiem, R., Guesmi, K., 2022. The bitcoin market reaction to the launch of central bank digital currencies. Res. Int. Bus. Financ. 63, 101800. Link [Access 20.01.2023].
Náñez Alonso, S.L., Jorge-Vazquez, J., Reier Forradellas, R.F., 2021. Central banks digital currency: detection of optimal countries for the implementation of a CBDC and the implication for payment industry open innovation. J. Open Innov.: Technol. Mark. Complex. 7 (1), 72. Link [Access 20.12.2022].
Nica, O., Piotrowska, K., Schenk-Hoppp, K.R., 2017. Cryptocurrencies: economic benefits and risks. University of Manchester. FinTech Work. Pap. 2. Link [Access: 24.12.2022].
Panetta, F., 2018. 21st century cash: central banking, technological innovation and digital currencies. Do We Need Central Bank Digital Currency 28–31. Link [Access 21.12.2022].
Ren, S., Culpan, T., 2017. Ethereum's wild ride needs to slow. Bloom. Bus. Link [Access 24.12.2022].
Rengasamy, E.L.A.N.G.O., 2012. Sovereign debt crisis in the euro zone and its impact on the BRICS's stock index returns and volatility. J. Econ. Finance. Rev. 2 (2), 37–46. Link [Access 05.01.2023].
Scharnowski, S., 2022. Central Bank speeches and digital currency competition. Financ. Res. Lett. 49, 103072. Link [Access 23.01.2023].
Scott, B., 2016. How can Cryptocurrency and Blockchain Technology Play a Role in Building Social and Solidarity Finance? UNRISD working paper,. Link [Access 23.12.2022].
Smales, L.A., 2022. Investor attention in cryptocurrency markets. Int. Rev. Financ. Anal. 79, 101972. Link [Access 17.04.2021].
Sun, H., Mao, H., Bai, X., Chen, Z., Hu, K., Yu, W., 2017. Multi-blockchain model for central bank digital currency. In: 18th International Conference on Parallel and Distributed Computing, Applications and Technologies (PDCAT), 2017. IEEE,. Link, 360-367 [Access 15.04.2021].
Thada, A., Kapur, U.K., Gazali, S., Sachdeva, N., Shridevi, S., 2019. Custom block chain based cyber physical system for solid waste management. Procedia Comput. Sci. 165, 41–49. Link [Access 25.01.2023].

Urquhart, A., 2018. What causes the attention of Bitcoin? Econ. Lett. 166, 40–44. Link [Access 24.01.2023].
Van Binsbergen, J.H., Koijen, R.S.J., 2010. Predictive regressions: a present-value approach. J. Financ. 65 (4), 1439–1471. Link [Access 14.04.2021].
Van Wijk, D., 2013. What can be expected from the BitCoin. Erasmus Univ. Rotterdam. Link, 18 [Access 14.04.2021].
Wadsworth, A., 2018. The pros and cons of issuing a central bank digital currency. Reserve Bank N. Z. Bull. 81, 1–21. Link [Access 22.12.2022].
Wang, Y., Lucey, B., Vigne, S.A., Yarovaya, L., 2022b. An index of cryptocurrency environmental attention (ICEA). China Finance Review International 12 (3), 378–414. https://doi.org/10.1108/CFRI-09-2021-0191/FULL/PDF.
Wang, Y., Lucey, B.M., Vigne, S.A., Yarovaya, L., 2022a. The effects of central bank digital currencies news on financial markets. Technol. Forecast. Soc. Change 180, 121715. Link [Access 16.04.2021].
Ward, O., Rochemont, S., 2019. Understanding central bank digital currencies (CBDC). Inst. Fac. Actuar. 1–52. Link [Access 23.01.2023].
Yelowitz, A., Wilson, M., 2015. Characteristics of Bitcoin users: an analysis of Google search data. Appl. Econ. Lett. 22 (13), 1030–1036. Link [Access 15.04.2021].
Yermack, D., 2017. Corporate governance and blockchains. Rev. Financ. 21 (1), 7–31. Link [Access 17.04.2021].
Zhang, T., Huang, Z., 2022. Blockchain and central bank digital currency. ICT Express 8 (2), 264–270. Link [Access 27.01.2023].
Lucey, M. B., Vigne, S. A., Yarovaya, L., and Wang, Y., 2022. The cryptocurrency uncertainty index. Finance Research Letters. 45, The cryptocurrency uncertainty index - ScienceDirect [Access 26..8.2023].