CRYPTOCURRENCIES AS A HEDGING TOOL DURING COVID-19 TURMOIL

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ABSTRACT

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Year 2020 brought with it the Covid-19 crisis and the restrictions, quarantines and lifestyle change it caused. Effects of the crisis were also reflected in economic indicators. For example, stock exchanges around the world experienced significant collapses, resulting in a decline in the values of assets of several investors. This master's thesis examines the usability of cryptocurrencies in hedging and safe haven purposes during Covid-19 crisis.

Based on the previous literature, it is challenging to draw consistent conclusions about the usability of cryptocurrencies for hedging against financial market risks. Previous findings vary widely depending on the model used, the time, and the asset risk hedged against. In general usability for hedging purposes does vary.

The Master's thesis also conducts an empirical study comparing the usability of Bitcoin, Ethereum and Tether, as well as gold, and German-, and US five-year government bonds, in hedging against the risks in the times-series development of DAX and SP500 indices. The data of the study are formed from daily observations from 1/2019 to 12/2020. The study utilizes the timeseries prices of assets examined, daily return percentages, and the Dynamic Contidional Correlations GARCH-model. According to the main results of the study, Tether provided the best short-term safe haven during the Covid-19 crisis. Bitcoin and Ethereum, on the other hand, were the most successful in securing long-term hedging and safe haven characteristics due to their significant increase in the value. Government loans performed the worst in hedging. In particular, the German government bond failed in the task because its yields have been at a negative side throughout the period considered.

Key words
Cryptocurrency, Bitcoin, Ethereum, Tether, Hedge

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Vuosi 2020 toi mukanaan koronakriisin ja sen aiheuttamat rajoitukset, karanteenit ja muutokset elämäntyyleihin. Kriisin vaikutukset näkyivät myös talouden mittareissa. Esimerkiksi pörssit ympäri maailman kokivat merkittäviä romahduksia, jonka seurauksena useiden sijoittajien omaisuuden määrät pienenivät. Tässä pro gradu tutkielmassa tarkastellaan kryptovaluuttojen käytettävyyttä suojautumiskäytössä talouden näkökulmasta.

Aiemman kirjallisuuden perusteella kryptovaluuttojen käytettävyydestä suojautumisessa rahoitusmarkkinoiden riskejä vastaan on haastavaa tehdä yhdenmukaisia johtopäätöksiä. Aiemmat löydökset vaihtelevat laajasti käytettävästä mallista, ajankohdasta ja suojattavasta riskistä riippuen. Yleisesti ottaen käytettävyyttä suojautumistarkoituksiin on kuitenkin olemassa, kylläkin vaihtelevissa määrin.

Pro Gradu tutkielmassa suoritetaan myös empiirinen tutkimus, jossa vertaillaan kryptovaluutoista Bitcoinin, Ethereumin ja Tetherin sekä muista sijoituskohteista kullan, Saksan ja Yhdysvaltojen viiden vuoden valtion velkakirjojen käytettävyyttä suojautumiseen DAXin ja SP500 indeksien hinnan kehittymiseen liittyviä riskejä vastaan. Tutkimuksen havainnot ovat päivittäisiä havaintoja aikavälillä 1/2019–12/2020. Tutkimuksessa käytetään hyödyksi sijoituskohteiden aikavälin aikaista hinnan kehitystä, päivittäisiä palautusprosentteja ja dynaamisten ehdollisten korrelaatioiden GARCH-mallia. Tutkimuksen tulosten mukaan parhaan lyhyen aikavälin suojasataman Covid-19 kriisin aikaan tarjosi Tether. Pitkän aikavälin suojaamisessa puolestaan parhaiten onnistuivat Bitcoin ja Ethereum niiden merkittävän arvon kasvamisen ansiosta. Valtioiden velkakirjat menestyvät huonoiten suojaamisessa. Eritoten Saksan valtionvelkakirja epäonnistui tehtävässä, koska sen tuotto on ollut negatiivisella tasolla koko tarkastelujakson ajan.

Asiasanat
Kryptovaluutta, Bitcoin, Ethereum, Tether, Taloudellinen suojaus

Säilytyspaikka
Jyväskylän Yliopiston Kirjasto

CONTENTS

1 INTRODUCTION 7

2 CRYPTOCURRENCIES 10
2.1 History and technical features of cryptocurrencies 10
2.2 Valuation of cryptocurrencies 11
2.3 Cryptocurrencies examined in the present thesis 12

3 CRYPTOCURRENCIES AS A HEDGING TOOL AND OTHER HEDGING TOOLS DURING FINANCIAL CRISIS 14
3.1 Covid-19 crisis and other financial crises 14
3.2 Cryptocurrencies as a hedging tool 15
3.2.1 Bitcoin as a hedge 16
3.2.2 Other cryptocurrencies 17
3.3 Other hedging tools during financial crisis 18
3.3.1 Gold 18
3.3.2 Government Bonds 19
3.4 Literature review conclusions 20

4 DATA AND METHODOLOGY 22
4.1 Data 22
4.1.1 Timeseries and Daily Returns 22
4.1.2 Descriptive statistics and unit root tests 31
4.2 DCC-GARCH model 32
4.2.1 Modelling 32
4.2.2 DCC-GARCH results 33

5 RESULTS AND ANALYSIS 42

6 CONCLUSIONS 44

REFERENCES 46

LIST OF TABLES AND FIGURES

Tables

Table 1 Sources for data 22
Table 2 Descriptive statistics for the logarithmic returns and descriptive statistics for returns of governmental bonds 31
Table 3 Unit root tests 32
Table 4 Descriptive statistics of DCC-rates against SP500 33
Table 5 Descriptive statistics of DCC-rates against DAX 37

Figures

Figure 1 Timeseries of DAX price quotations during the Covid-19 lockdown (Investing.com, 2021b) 7
Figure 2 Cryptocurrencies Market Capitalization (Coindance, 2021) 8
Figure 3 DAX index during Dotcom Bubble (Investing.com, 2021b) 15
Figure 4 DAX Index During Subprime crisis (Investing.com, 2021b) 15
Figure 5: Timeseries of Bitcoin's price quotations 23
Figure 6: Timeseries on Ethereum's price quotations 23
Figure 7 Timeseries on Tether's price quotations 24
Figure 8 Daily returns of Bitcoin 24
Figure 9 Daily returns of Ethereum 25
Figure 10 Daily returns of Tether 25
Figure 11 Timeseries on SP500 Index 26
Figure 12 Timeseries on DAX Index 26
Figure 13 Daily returns of DAX index 27
Figure 14 Daily returns of SP500 index 27
Figure 15 Timeseries on Germany five-year government bond 28
Figure 16 Timeseries on United States five-year government bond 28
Figure 17 Daily returns of Germany five-year government bond 29
Figure 18 Daily returns of United States five-year government bond 29
Figure 19 Timeseries on gold's price quotations 30
Figure 20 Daily returns of gold 30
Figure 21 DCC-rate between SP500 and Dax 33
Figure 22 DCC-rate between Bitcoin and SP500 34
Figure 23 DCC-rate between Ethereum and SP500 35
Figure 24 DCC-rate between Tether and SP500 35
Figure 25 DCC-rate between United States five-year bond and SP500 36
Figure 26 DCC-rate between Gold and SP500 36
Figure 27 DCC-rate between Bitcoin and DAX 38
Figure 28 DCC-rate between Ethereum and DAX 38
Figure 29 DCC-rate between Tether and DAX 39
Figure 30 DCC-rate between Germanys five-year bond and DAX 40
Figure 31 DCC-rate between gold and DAX 40

1 INTRODUCTION

Year 2020 was challenging for the global societies in many ways. People had to get used to new restrictive issues like quarantines, lockdowns of different places, and working remotely from home. These changes were also reflected in the financial markets. With the start of the first global lockdown in March 2020, stock markets around the world experienced a significant collapse. For example, as can be seen in Figure 1 the value of the German stock index DAX collapsed about 35 percent in a couple of weeks in March 2020.

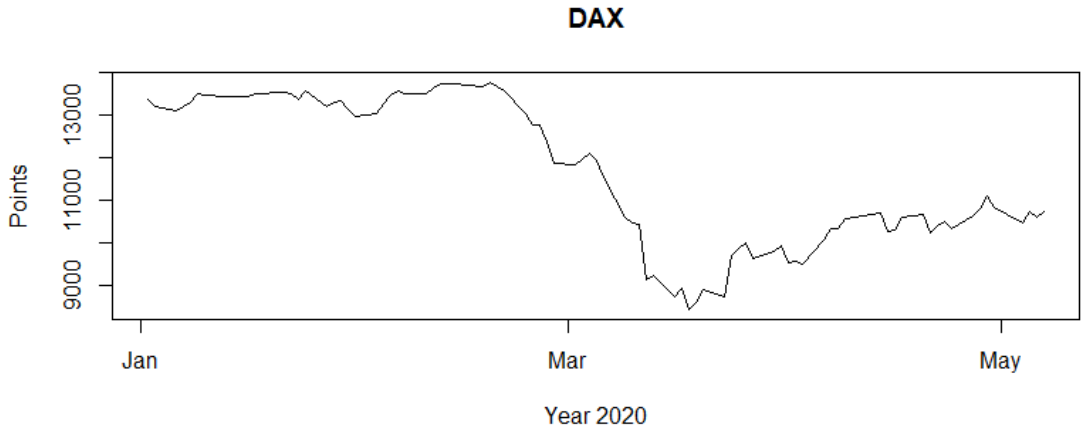

Figure 1 Timeseries of DAX price quotations during the Covid-19 lockdown (Investing.com, 2021b)

Most investors seek to maximize portfolio returns, so various assets are used to hedge against similar collapses. One option for hedging against the collapse is cryptocurrencies.

Cryptocurrencies are cryptography-secured virtual or digital currencies (Aggarwal & Kumar, 2021). Most of the cryptocurrencies operate under a peer-to-peer network (Corbet, Lucey, Urguhart & Yarovaya, 2019). For example, in the case of Bitcoin, a peer-to-peer network refers to a decentralized network based on blockchain technology that can make currency transfers (Aggarwal & Kumar, 2021). There are three types of cryptocurrencies: Bitcoin, altcoins and stablecoins. Bitcoin is the original cryptocurrency and is used as a means of payment as well as a store of value (Corbet et al. 2019). Altcoins, on the other hand, are a slightly broader concept. They are alternative cryptocurrencies to Bitcoin, and they vary widely. Some of them work similarly to Bitcoin, but some do not (Ciaian, Rajcaniova & Kancs, 2018). For example, the cryptocurrency Ethereum serves as a platform for the decentralized creation of applications and smart contracts (Aggarwal & Kumar, 2021). Stablecoins are also altcoins, but as their name implies, they are stable and less volatile cryptocurrencies and thus a class of their own (Ante, Fiedler, & Strehle, 2020). Different implementations of cryptocurrencies

and blockchain technology are discussed in more detail in the second chapter of the present thesis.

Cryptocurrencies are a relatively new asset class in the financial markets. Their history begun in year 2008 when Bitcoin was announced by Satoshi Nakamoto (Böhme, Christin, Edelman, & Moore, 2015). Since then, the total number of different cryptocurrencies has been increasing and in addition their market capitalization has increased significantly (Corbet et al. 2019). Despite the short history of cryptocurrencies, the amount of literature on them has been on the rise in recent years (Corbet et al. 2019). The present thesis seeks to find uniform conclusions from the existing literature on the use of cryptocurrencies in hedging. Answers obtained from the literature are varied and the answer must also be sought through the research carried out in the thesis.

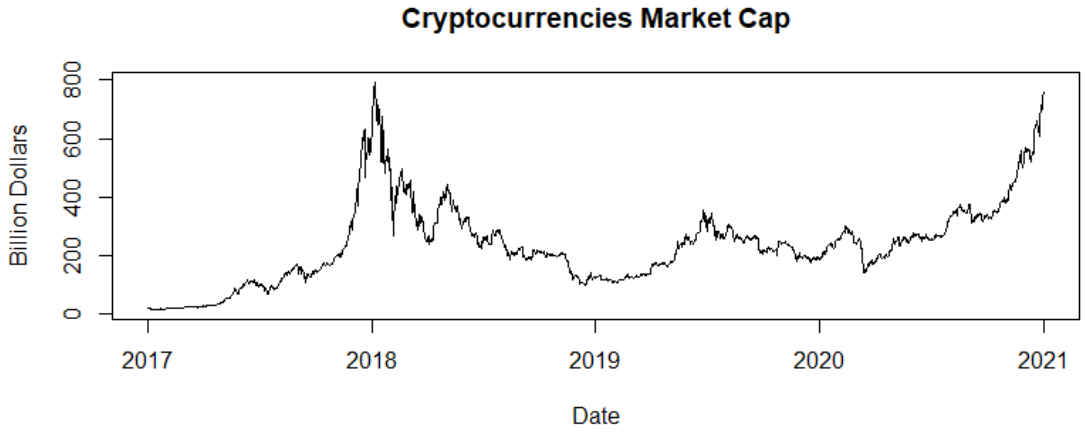

Figure 2 Cryptocurrencies Market Capitalization (Coindance, 2021)

The present thesis seeks answers to the following research questions:

RQ1: What are the hedging capabilities of a small set of most actively traded cryptocurrencies?

RQ2: Which cryptocurrency performed the best as a hedging tool during Covid-19 crisis?

To find the answers, the literature review of the existing literature related to the topic is used as an aid. In addition, the thesis conducts a study comparing the hedging and safe haven characteristics of cryptocurrencies (Bitcoin, Ethereum and Tether), gold and government bonds against the risks in the times-series development of DAX and SP500 indices. The study has been formed from the observations made by author during the period of 1/2019 - 12/2020. Time series analyses of long-term development, as well as Dynamic Conditional Correlations - Generalized AutoRegressive Conditional Heteroscedasticity model between different variables is used in the analysis of the research data. DCC-GARCH model provides information on how correlations between different assets evolve over time (Engle, 2002). Correlations, in turn, make it possible to assess the hedging characteristics of individual assets. The better the hedge, the more negatively it correlates with the target asset (Baur & Lucey, 2010).

The conclusions drawn from previous literature were varied so results in the present thesis are more based on the empirical study conducted in the thesis. According to the present study made, stablecoin Tether had the best short-term safe haven characteristics against the risks in the times-series development of DAX and SP500 indices during the Covid-19 turmoil. It was the only asset that was able to maintain its DCC-GARCH rates low and its price stable during the turmoil. Conlon, Corbet and Mcgee's (2020) findings also speak in favor of Tether's safe haven characteristics. In long-term, Bitcoin and Ethereum where the best options in hedging against DAX and SP500, since the significant raise in their price levels during the examination period offers investors decent incomes. Additionally, the low levels in DCC-GARCH rates during the study period improve their hedging properties. Similar findings on Bitcoin's hedging characteristics have been made by Shahzad, Bouri, Roubaud and Kristoufek (2020). The worst hedging opportunities were found in government bonds. For example, since the return on the German five-year government loan was at a negative level throughout the period, it would have entailed ongoing costs for the investor. The results of the analysis are detailed in Chapter Five.

The structure of the thesis is as follows. Chapters two and three deals with previous related literature. The former focuses more on the technical features of cryptocurrencies and the latter examines the usability of cryptocurrencies and other investments for hedging. The data and methodology of the present empirical study are explained in chapter four. Chapter five includes the results of the study. Chapter six contains the conclusions of the thesis.

2 CRYPTOCURRENCIES

This chapter provides information of technical features and history of cryptocurrencies as well as value formation behind them. Additionally, cryptocurrencies examined in the present thesis are briefly introduced in section three of this chapter.

2.1 History and technical features of cryptocurrencies

Cryptocurrencies are digital online cash systems that work without third party confirmation. Third party deficiency makes it possible to implement monetary transactions directly between users without going through an official financial institution. (Corbet et al. 2019). The year 2008 was the beginning for cryptocurrencies, when an anonymous group of writers named Satoshi Nakamoto published a different option for monetary transactions by publishing an article about Bitcoin as a peer-to-peer payment solution (Böhme et al. 2015). Bitcoin was made to fulfil a demand of a system that could implement online monetary transactions between parties without third party confirmation (Nakamoto, 2008). In traditional monetary transactions one party sends money or equivalent product to other and third party confirms that. In Bitcoins system transactions are verified by other users (Nakamoto, 2008). Additionally, in most cases traditional monetary assets' value is based on other assets' values, but with cryptocurrencies, value is based on the security of an algorithm, which can trace all transactions (Corbet et al. 2019). There is also other evidence of the value formation of cryptocurrencies, but it will be discussed in chapter 2.2. After the publication of Bitcoin, approximately 4500 other cryptocurrencies (investing.com, 2021a) have been released into cryptocurrency markets, and the number of currencies published increases over the time. These later published cryptocurrencies are labelled as Altcoins because they are an alternative cryptocurrency to Bitcoin. Additionally, methods of investing in cryptocurrencies have evolved over time. In the beginning, investors could only buy and hold, or mine cryptocurrencies. Nowadays, for example, they have the possibility to buy Bitcoin futures (Corbet, Lucey, Peat & Vigne, 2018).

A common feature for all cryptocurrencies is that they all use Blockchain technology. A Blockchain is a chain of individual parts. Each part of it contains current information and the latest block contains the latest information (Böhme, et al. 2015). Blockchain technology works as a distributed database, or public ledger, where all the information of executed transactions digital events is shared between parties (Crosby, Nachiappan, Pattanayak, Verma & Kalyanaraman, 2016). For example, in Bitcoin's blockchain, blocks contain information about amount of Bitcoin tokens sent, timestamp and information about who sent tokens

to whom (Nakamoto, 2008). However, Bitcoin and Altcoins operate differently. For example, there are differences in features, such as transaction speed, distribution methods, or hashing algorithms (Cagli, 2019).

An example of a blockchain technology in use is a Bitcoin transaction system, which works in simply as follows: In a transaction, party A sends amount of Bitcoin to party B, and the transaction is verified by other Bitcoin users (Nakamoto, 2008). As a whole, Bitcoin network is more complicated. Bitcoin network users have Bitcoin tokens, which are either bought from Bitcoin marketplace or gained from Bitcoin mining. An important difference to fiat money is that a Bitcoin network user does not have the ownership of the certain number of tokens in their wallet, they just have an information of the last transaction made, which proves that they have received a certain number of tokens in transaction (Bonneau, 2015). The number of tokens available in Bitcoin network increases when time passes, since new tokens are released to Bitcoin network from Bitcoin mining. In Bitcoin mining, users of the network verify transactions and try to solve numeric puzzles (Crosby et al. 2016). As a reward from solving puzzles and verifying transactions these miners get a certain amount of Bitcoin tokens as a revenue. The number of tokens received decreases over the time (Bonneau et al. 2015). According to estimates, the last Bitcoin tokens are added to system via Bitcoin mining until the year 2140 (Bonneau et al. 2015). Because of the decrease in reward tokens received from Bitcoin mining, transaction fees have raised in Bitcoin network (Easley, O'Hara & Basu, 2019). Without the rise in transaction fees, would cause the Bitcoin network to stop working, since without mining rewards, it is not profitable for miners to continue verifying transactions, and without miners, transactions could not be executed (Easley, O'Hara & Basu, 2019).

2.2 Valuation of cryptocurrencies

One of the most important questions for investors is how the value of cryptocurrencies is formed. It is almost common knowledge that cryptocurrencies have raised their value explosively during the recent decade. However, the formation of their value is not simply about their explosive rise. According to some of the official financial institutions, such as Finnish Financial Supervisory Authority (2019) and European Central Bank (2018), Bitcoin and other cryptocurrencies are just speculative assets. Speculative assets are assets, which value may rise or decrease without any reason. Therefore, their value is related to their supply and demand (Ciaian, Rajcaniova & Kancs, 2015). Additionally, Cheah and Fry (2015) specified that the fundamental value of Bitcoin is zero. This finding can be combined to apply into other cryptocurrencies as well. In comparison to traditional currencies, Bitcoin is similar in money supply and price level (Kristoufek, 2015), but price level includes a crash risk (Hui, Lo, Chau & Wong, 2020). Cheah's and Fry's (2015) finding about Bitcoin's susceptibility for bubbles also speaks in favour for price crash risk.

Regardless the releases of official financial institutions, there is evidence of reasons behind the valuation of cryptocurrencies deviant from the findings of Ciaian, Rajcaniova and Kancs (2015) about supply and demand as a main determinant for price. So far science proposed a couple of different theories for valuation of cryptocurrencies. A few individual factors behind valuation have been identified. One theory behind the value formation of Bitcoin is Peterson's (2017) model where Bitcoin's price follows Metcalfe's law in medium- and long-term. In Metcalfe's law, the value of a network grows as the square of the number of its users (Metcalfe, 2013). The Peterson's model can be extended to other cryptocurrencies as well, since its operation is based on the number of network users and not on the functionalities of Bitcoin. An alternative model for Peterson's model is introduced by Vliet (2018). In his model, Bitcoin is valued with Rogers' diffusion of innovation, which captures population parameters and growth rates. This model can also be extended to regard other cryptocurrencies as well, since this model is not dependent of Bitcoin's technology. A third theory behind valuating cryptocurrencies is that the value of cryptocurrency can be described by its cost of production (Hayes, 2017). According to Hayes (2017), the determinant for prices is the relative cost of production, and with the case of cryptocurrencies, it is electricity consumption. From these three theories mentioned above, it can be stated that the value of cryptocurrencies is related to the number of network users, the ability of users to adopt new technologies, and the cost of manufacturing cryptocurrencies.

In addition to the theories presented above, there are individual factors that can be used to explain the valuation cryptocurrencies. For example, according to Philippas, Rjiba, Guesmi and Goutte (2019), Bitcoin's price changes are partially explained by attention in social media platforms. What makes the pricing of cryptocurrencies special in comparison to other financial markets, is that users perceive the volatility of cryptocurrencies as a positive issue, while for other financial instruments it is perceived as a negative issue (Nadler & Guo, 2020). According to Nadler and Guo (2020), users' price volatility positively because they see it as an opportunity for higher returns. The price of Bitcoin can also be explained to be based on the derivatives associated with them (Alexander & Heck, 2020). According to Alexander and Heck (2020), the absence of regulation allows investors to manipulate the price of Bitcoin through derivatives. Similar findings are also applicable to other cryptocurrencies as they are not further regulated either. The risks involved in blockchain technology, in turn, are already included in the prices of cryptocurrencies (Nadler & Guo, 2020).

2.3 Cryptocurrencies examined in the present thesis

The present thesis examines the usability of the three cryptocurrencies: Bitcoin, Ethereum, and Tether as hedges during the Covid-19 crisis. In this section, the

technical properties of the above-mentioned cryptocurrencies are discussed briefly.

Bitcoin is a first published decentralized blockchain based cryptocurrency (Corbet et al. 2019). As mentioned earlier, it originated in 2008 when an anonymous group of authors called Satoshi Nakamoto raised the possibility of a self-sustaining decentralized currency (Böhme et al. 2015). Originally, Bitcoin was created with the ability to avoid using third parties in order to make money transactions (Nakamoto, 2008). According to Nakamoto (2008), financial institutes are used to prevent double-spending in monetary transactions, thus consumes resources that could be saved through a peer-to-peer network. In the case of Bitcoin, the peer-to-peer network in question refers to a blockchain, in which money transfers are verified by other network users (Nakamoto, 2008). Bitcoin differs from the other cryptocurrencies discussed in the present thesis in such a way that its main purpose is to pay and retain value (Böhme et al. 2015).

Ethereum is the second most popular and the second most valuable cryptocurrency (Beneki et al. 2019). Where Bitcoin is based on payments and value retaining, Ethereum is based on producing decentralized applications and smart contracts. In its implementation, Ethereum, like Bitcoin, utilizes blockchain technology and enables the above-mentioned applications and smart contracts to operate without downtime and fraud (Aggarwal & Kumar, 2021). Ethereum may also be used for payment purposes in addition to these other features (Ethereum, 2021). In this case, instead of Ethereum, we speak of Ether, which is Ethereum's own cryptocurrency (Ethereum, 2021).

Tether is one of the most famous stablecoins (Aggarwal & Kumar, 2021). Like the other cryptocurrencies discussed in the present thesis, Tether is based on blockchain technology (Kristoufek, 2021). The implementation of stablecoin differs slightly from the implementation of traditional cryptocurrencies. The price of stablecoin is most often pegged to one of the fiat currencies, or to some other stable asset, when other cryptocurrencies float freely (Baur & Hoang, 2021). The aim of stablecoin is to keep the price as consistent as possible (Wang, Ma & Wu, 2020). Traditional cryptocurrencies are known to be highly volatile, so stablecoins can be used as cryptocurrencies' own means of payment or, conversely, as a store of value (Wang, Ma & Wu, 2020). Therefore, they may provide options in hedging as well because their value should be the same when markets face extreme changes (Baur & Hoang, 2021).

3 CRYPTOCURRENCIES AS A HEDGING TOOL AND OTHER HEDGING TOOLS DURING FINANCIAL CRISIS

Internet is full of varying information about cryptocurrencies' hedging capabilities. Therefore, this section provides a literature review on the usability of cryptocurrencies as a hedge and as a safe haven, as well as the usability of gold and government bonds for similar purposes. Additionally, a short conclusion of the complete literature review is at the end of this chapter.

To clarify matters, it is important to acknowledge the meaning of a hedge. Hedges are investment assets that are negatively correlated with another assets value changes on average (Baur & Lucey 2010). Another reviewed asset in this paper is a safe haven. Safe haven asset is an asset which correlates negatively with other assets during extreme market changes such as financial crisis (Baur & Lucey 2010).

3.1 Covid-19 crisis and other financial crises

During a financial crisis, the values of financial assets drop enormously, companies and individuals face difficulties with payments, and financial institutions suffer shortages in liquidity (Kenton & Scott, 2020). There have been several financial crises during the 21st century. Dotcom bubble (Figure 3) at the turn of the millennium when value of most technology companies collapsed (Hayes, 2019), Subprime crisis (Figure 4) where wrongly issued mortgages caused the global financial crisis (Kenton, 2019) and the recent crisis caused by Covid-19 (Xu, 2020). In common for all these crises is that stock markets and other financial assets suffered significant losses in their value. With the case of Covid-19 crisis, there are evidence of negative correlation between stock market prices and the pandemics' confirmed cases per day rate (Ashraf, 2020). Therefore, investors have started to seek hedging strategies against different kinds of shocks. Potential hedges against stock markets could be cryptocurrencies, gold, or government bonds.

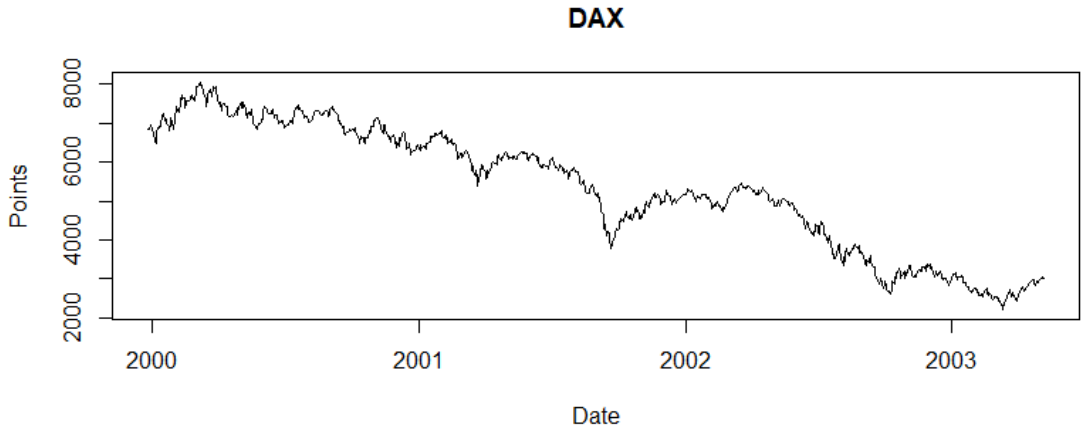

Figure 3 DAX index during Dotcom Bubble (Investing.com, 2021b)

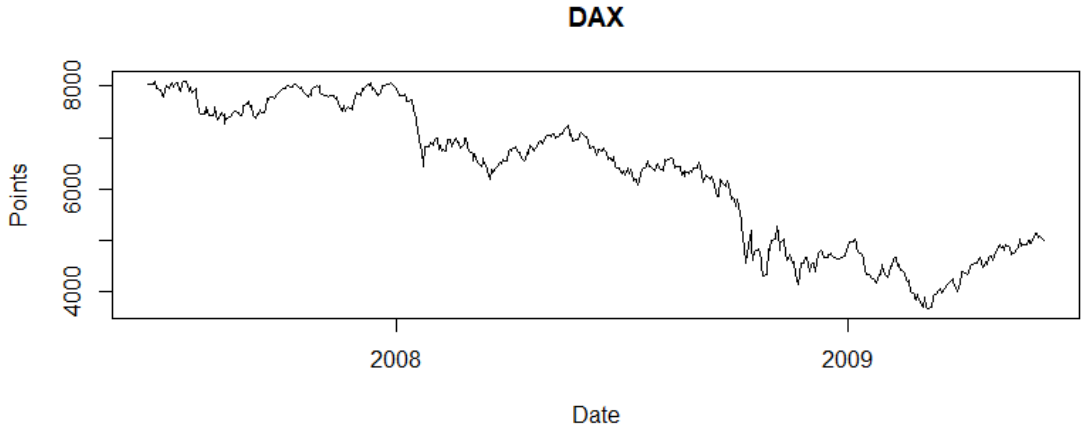

Figure 4 DAX Index During Subprime crisis (Investing.com, 2021b)

3.2 Cryptocurrencies as a hedging tool

Findings about the usability of cryptocurrencies as hedges have varied over the years. The results would appear to be strongly tied to time, currency, and target asset. Even between individual studies, there may be discrepancies in the findings. For example, according to Bouri, Shahzad and Roubaud (2020) there are significant heterogeneity between safe haven or hedging attributes across different cryptocurrencies within a sample period of about three years. Based on their research Ethereum, Dash and Nem are hedges against for a few US equity sectors. While Bitcoin, Ripple and Stellar are safe havens for all US equity indices and Litecoin and Monero are a safe haven for aggerate US equity index and selected sectors. Therefore, it is impossible to draw consistent conclusions from their study since there are differences in cryptocurrencies' hedging capabilities against

different assets. Nevertheless, similarities can be found in other studies, and estimates can be made about the usability of cryptocurrencies as a hedge and as a safe haven by combining studies.

3.2.1 Bitcoin as a hedge

As Bitcoin is the largest and most famous cryptocurrency (Corbet et al. 2019), it also has the most research results about usability as a hedging tool. According to earlier studies, it has some hedging capabilities and safe haven characteristics against different assets and markets. For example, Bouri, Shahzad, Roubaud, Kristoufek and Lucey (2020) found out that Bitcoin has superiority over gold and commodities in safe haven characteristics against different stock markets. In addition, according to Bouri, Molnár, Azzi, Roubaud and Hagfors (2017), Bitcoin is suitable for diversification purposes and works as a safe haven against Asian stock markets, but it is a poor hedge on average against different assets. Additionally, Wang, Tang, Xie and Chen (2019) discovered that Bitcoin can be used as a safe haven for Chinese stock markets, but according to them, Bitcoin can be used as a hedge against other stock markets as well. Already based on these three studies there are no singe correct answer about the usability of cryptocurrencies for hedging.

To clarify the findings from the literature, it is worthwhile to go through more findings from research articles. In addition to the findings already mentioned, Bitcoin is a strong hedge against different indices worldwide on a monthly basis. But its hedging properties are not strong on a daily or a weekly basis. (Chan, Le & Wu, 2019). Additionally, the findings of Shahzad et al. (2020) justify that Bitcoin has safe haven and hedging characteristics against different stock markets. According to these two studies, there are clear possibilities for using Bitcoin as a hedge or as a safe haven. Still there are opposing results available about hedging capabilities. Garcia-Jorcano and Benito (2020) agree with Shahzad etc. (2020) on the usability of Bitcoin as a hedge, but according to them, it has hedging characteristics on a short-term, but it may fail on a longer term. However, the findings of Kliber, Marszalek, Musialkowska and Świerczyńska (2019) go far more upstream with others. According to them, Bitcoin is a weak hedge against Venezuelan, Japanese, Chinese, Swedish, and Estonian stock markets. They also state that Bitcoin has safe haven characteristics only against Venezuelan markets. Additionally, it is worth noting that Bitcoin has its own idiosyncratic shocks, which causes harm to its hedging properties against other market risks (Kurka, 2019). In addition, Bitcoin market shocks may cause shocks to other markets (Kurka, 2019). It is notable to mention that according to Corbet et al. (2018), Bitcoin futures are not an effective hedging tool. In summary, the usability of Bitcoin as a hedge strongly depends on the market hedged against and the period examined.

There is also scientific evidence available that Bitcoin and other cryptocurrencies can be used as a hedge and a safe haven against other asset classes than stock markets as well. For example, Bitcoin can be used for hedging or safe haven

purposes against American dollar (Dyhrberg, 2016), FTSE index (Dyhrberg, 2016), OVX (Das, Le Roux, Jana & Dutta, 2020) and weakly against economic policy uncertainty (Wu, Tong, Yang & Derbali, 2019). Again, the strength for hedging and safe haven purposes depends heavily on the timing and the asset class that is hedged.

3.2.2 Other cryptocurrencies

While Bitcoin is the largest and the most famous currency, other cryptocurrencies receive less attention in science (Corbet et al. 2019). Despite the lack of attention, there are some research articles available about usability of other cryptocurrencies in hedging against stocks and in general. It has already been noted that the usability of altcoin as a hedge depends on the altcoin used (Bouri, Shahzad & Roubaud, 2020). Mariana, Ekaputra and Husodo (2020) examined safe haven properties of Bitcoin and Ethereum during Covid-19 crisis, and according to their research, both currencies are safe havens in short term against stock markets, but from these two, Ethereum performs slightly better. According to Conlon, Corbet and Mcgee (2020), Tether maintained its safe haven properties against international equity markets better than Bitcoin and Ethereum during Covid-19 crisis, since it was able to maintain its peg to the US Dollar. They still point out the fact that Tether is not always able to maintain its course to the US dollar. However, the opposite view is brought by Huynh, Nasir, Vo, and Nguyen (2020), who state that Tether is significantly volatile, and therefore Bitcoin is the most appropriate instrument for hedging. Similarly, Thampanya, Nasir & Huynh (2020) state that cryptocurrencies do not act as a good hedge against stock markets. Mensi, Al-Yahyaee, Al-Jarrah, Vo, and Kang (2020) for their part argue that during a crisis, investors should hold less Bitcoin than other cryptocurrencies for minimizing risks and maintaining consistent returns. Cheema, Faff and Szulczuk (2020) agree saying that Bitcoin does not serve as a safe haven against ten largest stock exchanges during a Covid-19 pandemic, but stablecoin Tether does.

As visual above, it is impossible to form a coherent overall picture based on existing research results. The results vary greatly based on of changes in timescale and the assets studied. However, the findings of Pengfei, Wei, Xiao & Dehua (2019) are quite relevant for the present thesis. They formed three key takeaways from their research: cryptocurrencies are a safe haven but not a hedge against the international indices, the safe haven property is more pronounced in subgroups with larger market capitalization and higher liquidity, and the safe haven property is more pronounced in developed markets. What is the most important, is to see that there is evidence that cryptocurrencies can be used for hedging. However, Charfeddine, Benglagha and Maouchi (2020) state that Cryptocurrencies are suitable for diversification purposes, but they are poor hedging tools. When all these findings are considered, it is clearly worthwhile to further examine the usability of cryptocurrencies as a hedging tool.

3.3 Other hedging tools during financial crisis

To get a comprehensive picture of the usability of cryptocurrencies for hedging, it is also desirable to explore other hedging methods. Gold and government bonds as a hedging tool, have been selected for closer inspection in this paper.

3.3.1 Gold

One of the best known and most researched methods for hedging is gold. Basic idea behind the usability of gold for hedging is that its statistical properties have negative correlation with equities (Lucey, Peat, Šević & Vigne, 2019). Especially in times of financial crises and during extreme market fluctuations, gold has acted as a reliable hedge. According to Junttila, Pesonen and Raatikainen (2018) the correlation between stock markets and the gold market becomes negative around the times of financial crises. Therefore, gold can be used in hedging during those times. Similar findings have been made by Nguyen, Bedoui, Majdoub, Guesmi and Chevellier (2020), who state that in turmoil and high uncertainty periods, gold is a stabilizing asset with substantial safe haven property.

Despite the similarities in hedging characteristics of gold during financial crises, scientific evidence on hedging against stock markets has varied over the years, but in overall usability is at a good level. For example, according to Baur and Lucey (2010), gold is a hedge against stocks on average and a safe haven in extreme stock market conditions. They indicate that the safe haven characteristics of gold are short-lived and will only last for 15 days, after which investors begin to suffer losses (Baur and Lucey, 2010). The same discovery has been made by Dee, Li and Zheng (2013), who state that in short term gold cannot always hedge against stock or inflation risks, but it is a good hedge in longer term. Baur and Lucey (2010) also recommend buying gold during extreme negative shocks and selling it once the volatility of stocks has returned to normal. The findings of Beckmann, Berger and Czudaj (2015) are in line with Baur and Lucey (2010). According to Beckmann, Berger and Czudaj (2015) gold is a hedge and a safe haven against different markets and indices, but its hedging abilities are market specific. There are also conflicting findings about the usability of gold for hedging. For example, according to Zhang, Wang, Xiong and Zou (2020), Chinese gold spots and futures are not effective hedges against stocks, bonds, and oil. Their findings can be explained by the location of the markets in their studies. Dee, Li and Zheng (2013), report that gold is not a safe haven for China related stocks or inflation in general. Although there are a few negative findings about the usability of gold in hedging against the Chinese stock markets, usability in hedging may still exist there as well. According to Arouri, Lahiani and Nguyen (2015), gold serves as a safe haven for stocks in the Chinese markets during the financial crisis. Their findings indicate that adding gold to a portfolio of Chinese stocks improves its risk-adjusted return and help in hedging effectively against stock risk exposure

over the time. Findings about the usability of gold for hedging also exist in other stock markets.

Based on several sources, gold acts as a hedge against US stock markets (Baur & McDermott, 2010; He, O'Connor & Thijssen, 2018; Hood & Malik, 2013). In terms of safe haven characteristics against US stock markets, there are discrepancies in the findings. According to Baur and McDermott (2010) gold is a safe haven against US stocks but according to He, O'Connor and Thijssen (2018) it is not a safe haven for them. Compromise between these two arguments is made by Hood and Malik (2013), who state that gold has weak safe haven characteristics against US stock markets. For European stock markets, the situation is not much different. Gold is a hedge and a safe haven for European stock markets (Baur & McDermott, 2010) and it works as a hedge against UK stock markets (He, O'Connor & Thijssen, 2018). However, gold does not act as a hedge against the Japanese, Canadian, Australian, or large emerging stock markets (Baur & McDermott, 2010). In hedging against the emerging stock markets, Basher and Sadorsky (2016) recommend using oil instead of gold. It is noteworthy to mention that according to Baur and McDermott (2010) during the financial crisis, gold acts as a strong safe haven in most developed stock markets.

There is also other usability for gold in hedging. For example, according to Nguyen et al. (2020), gold can be used in hedging against the depreciation value of USD, EUR, and JPY. Gold can also be used in hedging against USD rate movements, and it is a safe haven against extreme USD rate movements (Reboredo, 2013). Also, according to Ciner, Gurdgiev and Lucey (2013) gold is a safe haven against exchange rates in United States and United Kingdom.

3.3.2 Government Bonds

Other typical hedging method against depreciation of stock markets are government bonds. Government bonds are debt securities, which are issued by a government. In most cases, they are issued for financing governments budget. Negative correlation between stock markets and government bonds offers an opportunity for government bonds to act as a hedging tool for stocks during financial crises. Scientific evidence on how government bonds act as a hedging tool is quite one-sided, and several findings approve government bonds over other hedging methods, but alternative results also exist. For example, bonds do not act as hedging tools against stocks in short term, but in longer term they do (Lin, Yang, Marsh & Chen, 2018). One of the positive findings of bonds' usability in hedging against stocks are represented by Bahmani-Oskooee, Ghodsi and Hadzic (2020), who state that against different industries in stock markets, treasuries have the best hedging properties among gold, silver, and oil. The superiority of treasuries over gold in hedging against stock markets is also explained with its lover correlation with market returns (Dicle & Levendis, 2017). One other difference between gold and government bonds is that gold is a passive safe haven asset where government bonds are an active safe haven asset (Liu, 2018). One notable mention is the research of Habib and Stracca (2015), who examined that is there

one global safe haven asset, and as a result they ended up with US short-term government debt. According to their research, it is the best global safe haven, but it is still imperfect.

There is also evidence of government bonds' hedging capabilities without comparison to other hedging methods. Again, research findings share mostly similar opinions about usability in hedging. According to Kopyl and Lee (2016), during the months with large declines in financial markets, US treasuries and Japanese Yen acts as a strong safe haven. A similar view is offered by Cheema, Faff and Szulczuk (2020), who state that during 2008 global financial crisis, and during the Covid-19 pandemic, US treasuries acted as a strong safe haven. The findings from Gupta, Subramaniam, Bouri and Ji (2021) are no exception, since they indicate US treasury securities can hedge financial market risks during Covid-19 pandemic. Hsu, Lee, and Lien (2020) report slightly opposite results than others, because according to them, negative correlation between stocks and bonds rise during normal increasing market uncertainty periods but decreases during extreme market uncertainty periods. In other words, there is usability for bonds in hedging, but they do not work as a safe haven. In addition to usability against stock markets, government bonds can be used in hedging against equity markets (Ciner, Gurdgiev & Lucey, 2013).

3.4 Literature review conclusions

The main purpose of the present thesis is to explore the usability for cryptocurrencies in hedging against the stock market crash caused by Covid-19 crisis. Previous literature did not give a coherent answer to this question. Results have varied in studies greatly depending on the timescale, cryptocurrency examined, and the asset that is being hedged against. For example, according Shahzad et al. (2020) Bitcoin is suitable in hedging against different stock markets. Meanwhile Kliber et al. (2019) identified that Bitcoin has only weak hedging characteristics against different stock markets worldwide, and that it only has safe haven properties against Venezuelan stock markets. Already these two findings make it impossible to form a coherent conclusion independent of time, cryptocurrency, and the examined asset.

Another purpose of the present thesis is to find out which one out of three assets examined performs the best in hedging against a stock market crash caused by Covid-19 pandemic. According to previous literature there are possibilities for every asset class to perform as a hedge asset during crisis. A review identifies that the best probabilities in succeeding hedging are with cryptocurrencies. Already the findings of Bouri et al. (2020) raise this probability since Bitcoin was discovered to act as better safe haven than gold against different stock markets. Although performance of gold and government bonds in hedging have been better in the literature examined, it still can be trusted that cryptocur-

rencies may outperform them. Literature about the hedging capabilities of cryptocurrencies is newer, and therefore the validity of the results can be better. Most of the literature about hedging capabilities of gold and government bonds is older, and therefore it may be invalid nowadays. In order identify the best-performing hedge, the hedging characteristics of all three asset classes will be further examined through the empirical study in the next chapter.

4 DATA AND METHODOLOGY

This chapter reviews the data used in the study, the methodology of the study, and the results of the DCC-GARCH model. The first section of the chapter examines the timeseries development and daily returns of the included assets during the examined period. The second part of the chapter consists of an introduction to the DCC-GARCH model, and the results obtained from it, as well as their graphs.

4.1 Data

4.1.1 Timeseries and Daily Returns

Data is formed of 492 daily observations during the period between 1/2019 and 12/2020. Cryptocurrency related data is collected from Coindesk.com since it is the most used database in previous cryptocurrency literature (Corbet et al. 2019). Data for other variables is collected from Investing.com. Cryptocurrency prices are reported as dollars per cryptocurrency. Data is modified to fit better for time series analyses by deleting unavailable values from dataset. Therefore, comparison between variables is made easier and more reliable. In addition to the timeseries evolution of the assets, logarithmic daily return percentages are formed for them with the following equation:

$$r_t = 100 \times [\ln(P_t) - \ln(P_{t-1})]$$

Table 1 Sources for data

Asset	Period	Source
Bitcoin	1/2019-12/2020	Coindesk.com
Ethereum	1/2019-12/2020	Coindesk.com
Tether	1/2019-12/2020	Coindesk.com
Dax	1/2019-12/2020	Investing.com
SP500	1/2019-12/2020	Investing.com
Gold	1/2019-12/2020	Investing.com
US5Y-Rate	1/2019-12/2020	Investing.com
GER5Y-Rate	1/2019-12/2020	Investing.com

Figures 5, 6 and 7 describe the price quotations of cryptocurrencies used in this study. For cryptocurrencies, the price development of Bitcoin and Ethereum is mostly similar for the considered period. The development of Tether's price, on the other hand, differs greatly from the development of the mentioned two. Where Bitcoin and Ethereum have more fluctuation in their price

movements, Tether stays more stable excluding three different short term price drops. The decreases in the value of Tether are also much more moderate than the fluctuations in the value of Bitcoin and Ethereum. By the most important time for this study, i.e., the beginning of March 2020, there is no corresponding clear drop in the price of tether, which can be discovered in the price development of Bitcoin and Ethereum. However, Tether's price development lacks a great price increase which ranks in the Bitcoin and Ethereum charts at the end of the review period. It is also noteworthy that the recovery of Ethereum and Bitcoin from the Covid-19 turmoil has been rapid as their prices are back to pre-fall levels just a few months after the crisis.

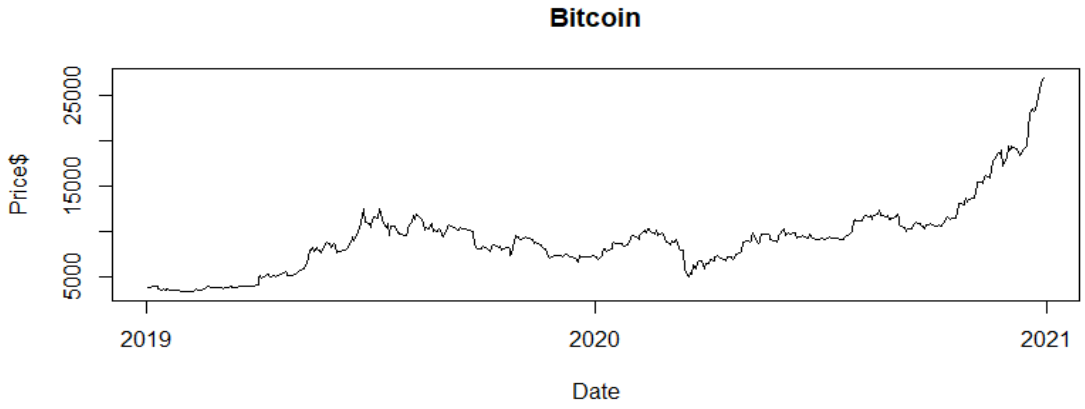

Figure 5: Timeseries of Bitcoin's price quotations

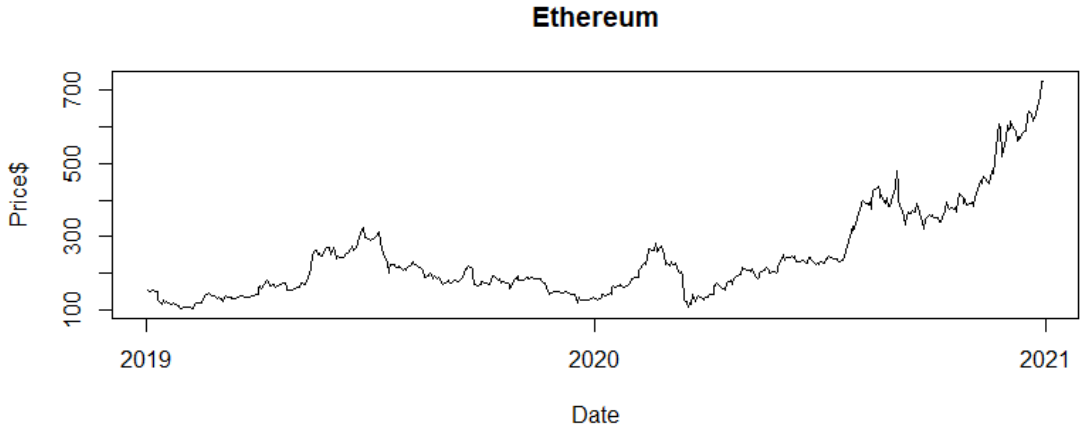

Figure 6: Timeseries on Ethereum's price quotations

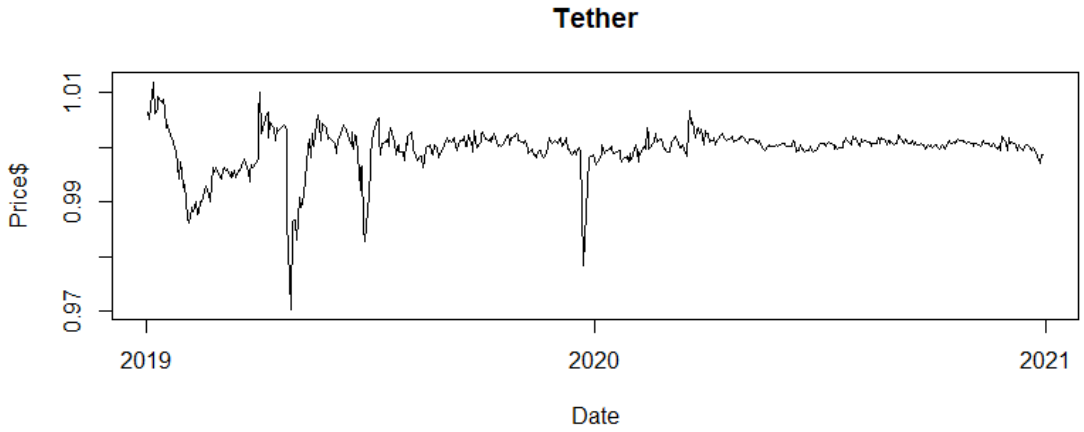

Figure 7 Timeseries on Tether's price quotations

Examining the daily returns of Bitcoin, Ethereum, and Tether in figures 8, 9, and 10 only confirms the findings from the examination of time series obligations. Bitcoin and Ethereum remain to have some similarities in their development, and Tether clearly differs from them. Bitcoin and Ethereum have clear spikes in March 2020 while Tether does not. Also, standard deviation of Tethers daily returns is significantly smaller than it is with other cryptocurrencies examined. For Tether, a longer-term trend change in the daily return figure is also noticeable. After the Covid-19 crisis, Tether's daily return percentages levelled off further. Thus, Tether's stablecoin properties have only improved as the review period nears its end.

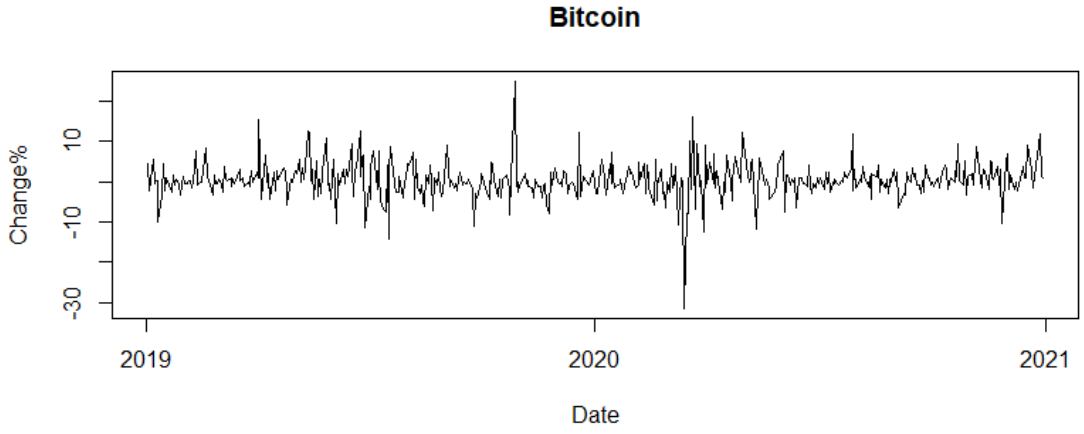

Figure 8 Daily returns of Bitcoin

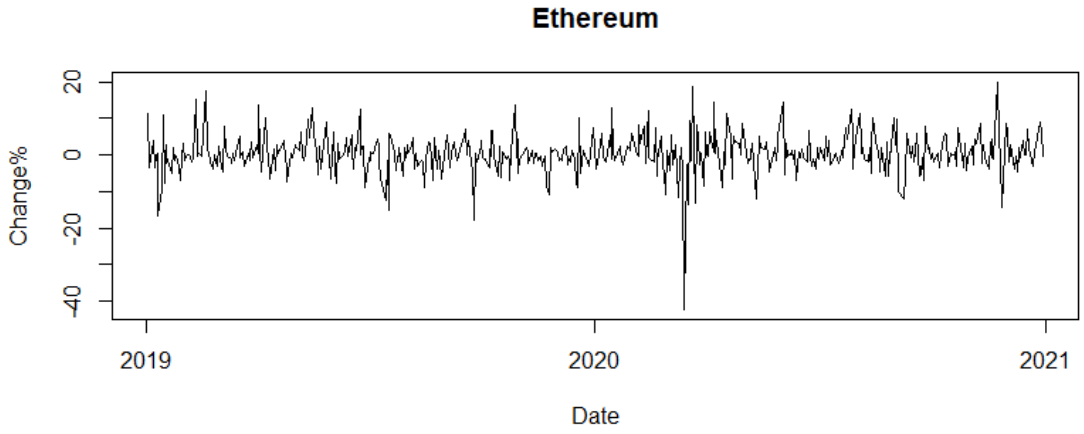

Figure 9 Daily returns of Ethereum

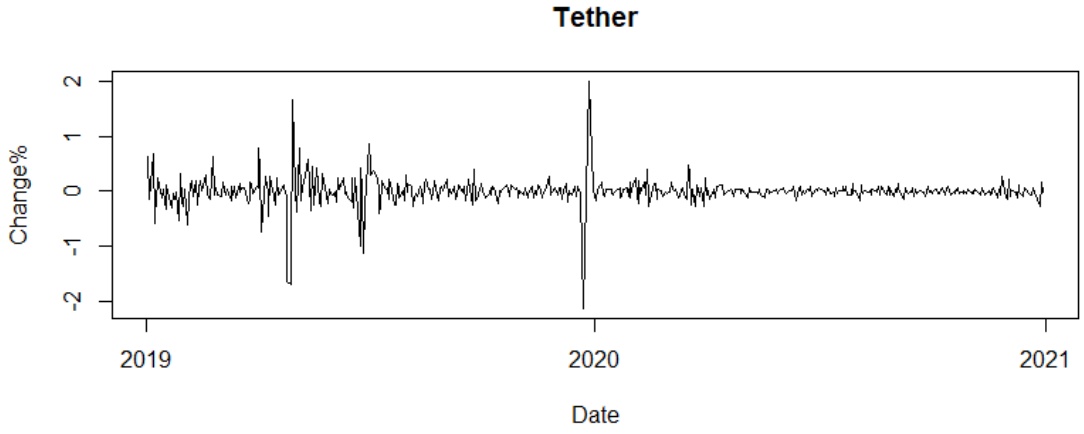

Figure 10 Daily returns of Tether

Figures 11 and 12 illustrate timeseries development of DAX and SP500 indices' price quotations. From the figures, it can be observed that during the studied period, changes in SP500 and DAX indices are very close to similar. The value of both was on a steady rise before facing the Covid-19 crisis. At the worst part of the crisis, in March 2020, the value of both indices clearly collapsed and since then the rise has been relatively steady. The value of SP500 has risen slightly more than DAX, as SP500 has already reached higher value than it had before corona crisis. Meanwhile DAX was nearly in the same numbers in December 2020 as it was before crisis. Therefore, it can be said that according to these figures, investors' trust in SP500 has recovered faster from the Covid-19 crisis than it has in DAX. The figures of both indices also show the uncertainty in the investment market caused by the US presidential election in the November of 2020.

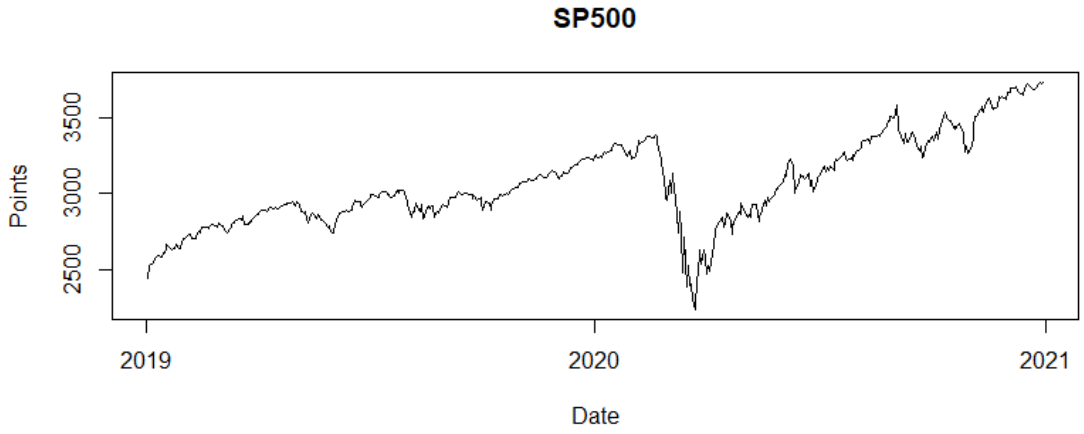

Figure 11 Timeseries on SP500 Index

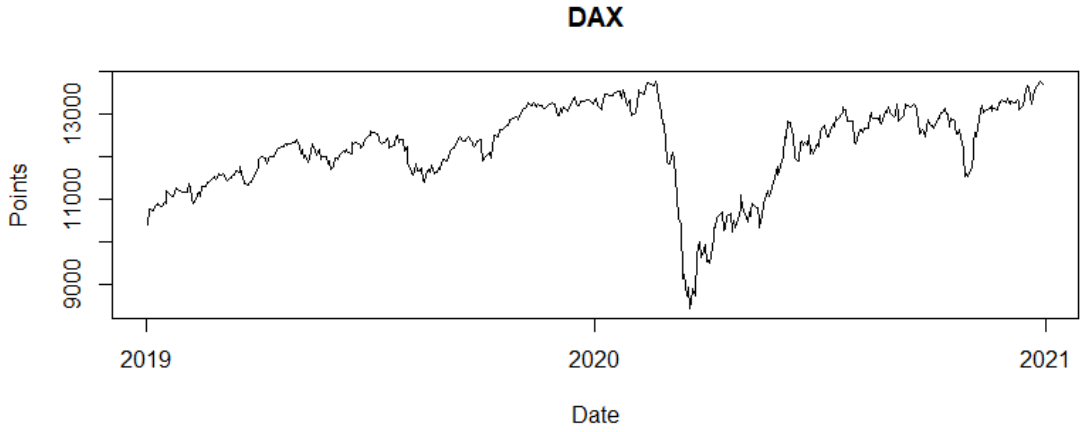

Figure 12 Timeseries on DAX Index

Daily returns of DAX and SP500 in figures 13 and 14 have some similarities but there are some differences as well. Daily returns of both indices were more stable before Covid-19 turmoil in March 2020. During the turmoil, both indices had negative returns and standard deviation rose significantly. The Covid-19 turmoil also caused a long-term trend to change in the figures of daily returns for both indices, as the standard deviation of both figures has been significantly larger since the crisis than it was before. The difference between the indices is that the moments of large fluctuations in SP500's daily returns lasted longer than they did on DAX.

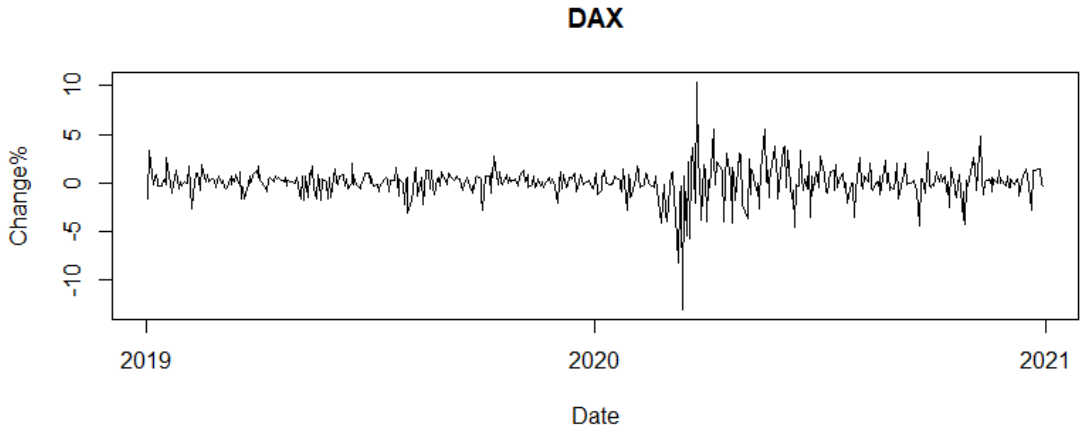

Figure 13 Daily returns of DAX index

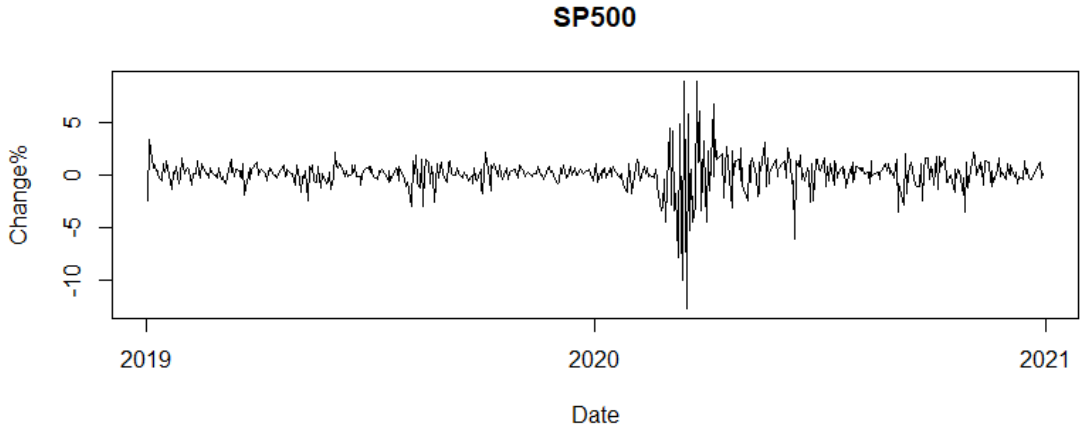

Figure 14 Daily returns of SP500 index

Germanys five-year loan and the United States' (US) five-year loan are both governmental bonds but their rate development under the studied period differs from each other as can be seen from the figures 15 and 16. Both suffered a clear fall in rates' value during the worst moments of the crisis in March 2020.There is difference in how they developed after the drop. Rate of GER5Y loan bounced back in a short period of time. Meanwhile US5Y loan stayed down for the end of the studied period.

It is worth remembering that the interest rate on the German loan was already on the negative side, so dropping it further is more difficult than the American interest rate, which was on the positive side. Because of this, the German rate's bounce back was slightly more likely to happen than the US5Y.

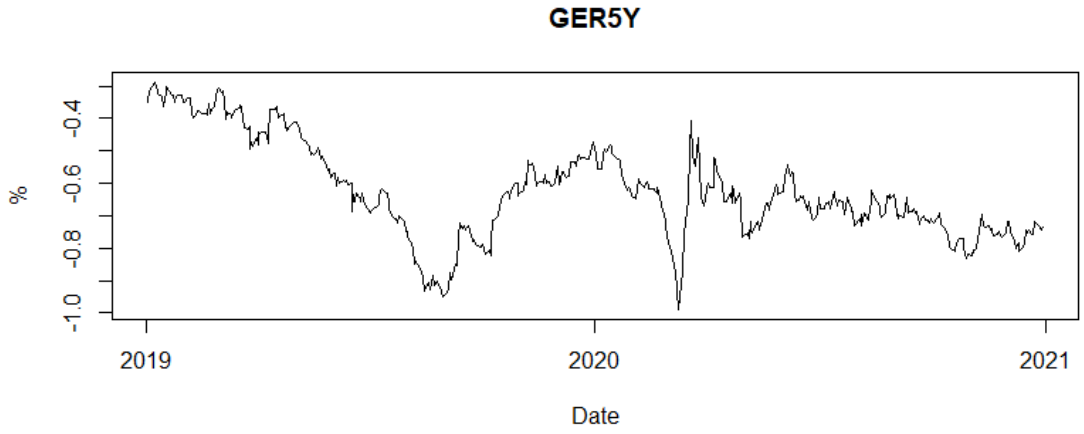

Figure 15 Timeseries on Germany five-year government bond

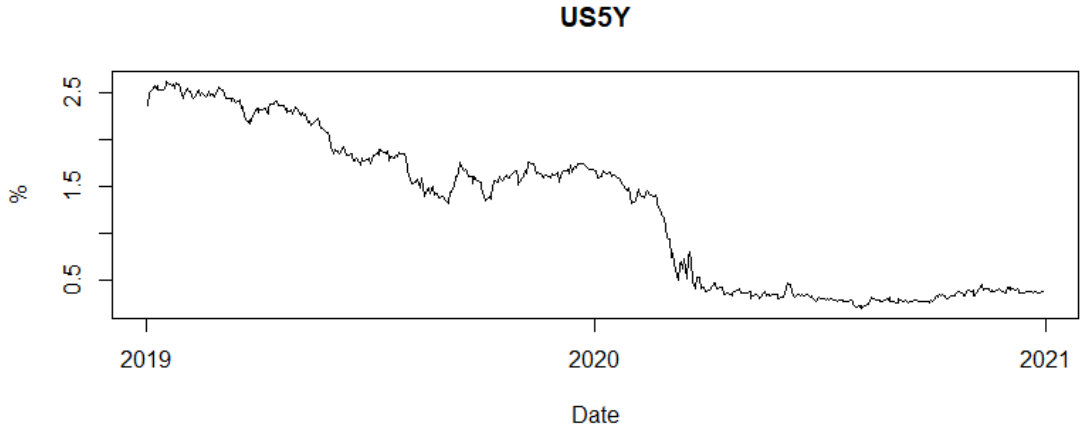

Figure 16 Timeseries on United States five-year government bond

In daily returns illustrated in figures 17 and 18, Germany's five-year rate and the US' five-year rate has some differences as well. Where US5Y rate was stable before Covid-19 crisis, GER5Y rate was more volatile. Both had huge volatility immediately after the Covid-19 outbreak. Germany's rate quickly recovered to similar volatility levels as before crisis, but US' rates volatility has increased after March of 2020. However, the comparison of daily returns is not very relevant for government bonds, as the yield on them is based on their interest rate and not on their daily price fluctuations.

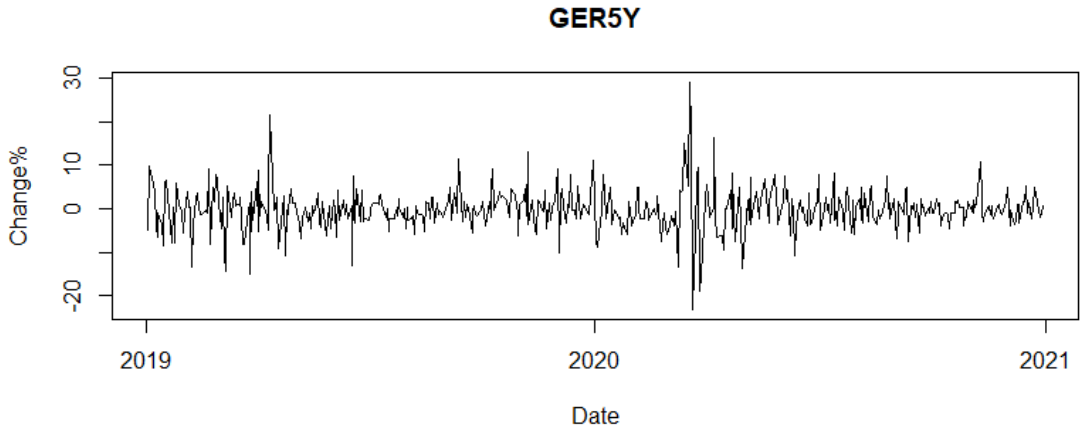

Figure 17 Daily returns of Germany five-year government bond

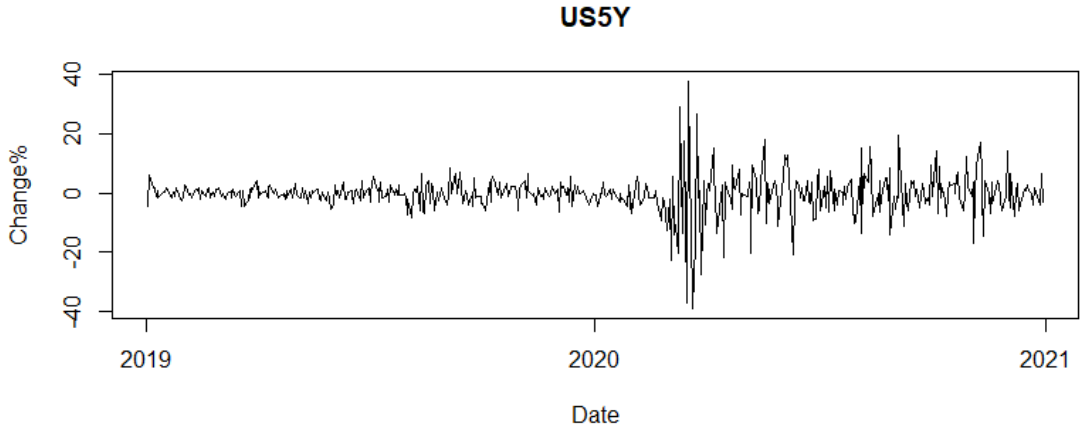

Figure 18 Daily returns of United States five-year government bond

From figure 19, it can be observed that as a commodity asset, gold provides totally different figures to this study. Its price development has been clearly more stable than the others, except for Tether, which value has remained almost the same throughout the examined period. The value of gold has been steadily rising since the beginning but declining slightly towards the end. It also suffered a price drop during the Covid-19 turmoil, but it recovered to same price levels as before crisis almost immediately.

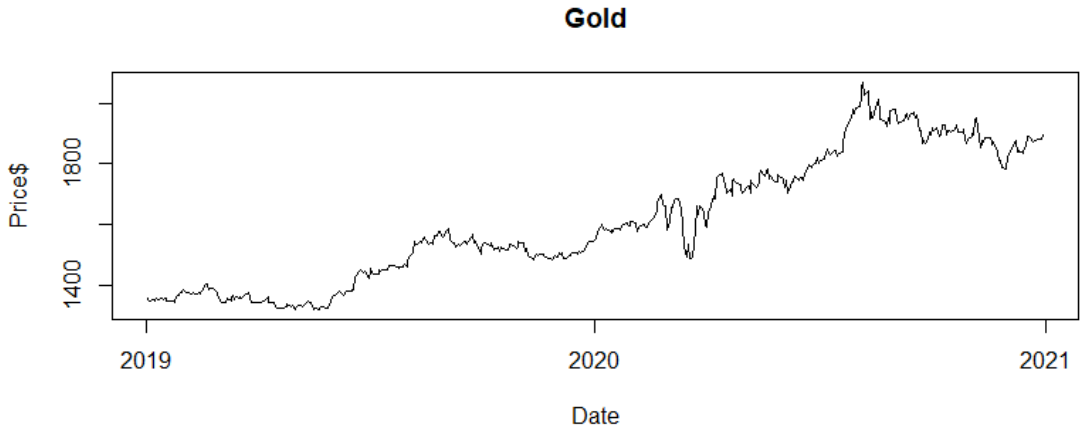

Figure 19 Timeseries on gold's price quotations

Covid-19 seems to have had similar effects to daily returns of Gold than it has had to other examined variables. Before Covid-19 turmoil in March 2020, the volatility of Gold daily returns was smaller and thus the price development was more stable. The Covid-19 turmoil caused a long-term trend of change in the development of daily returns, which resulted in a significant increase in gold price volatility after the turmoil.

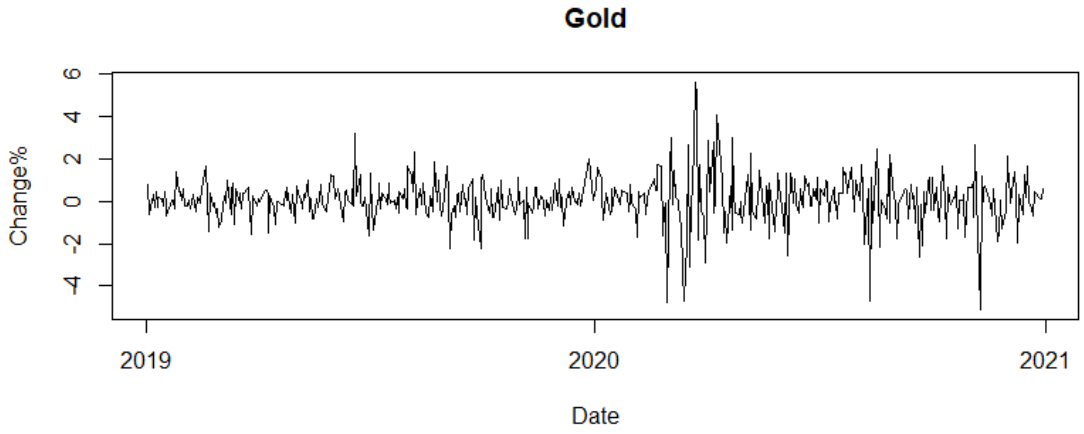

Figure 20 Daily returns of gold

As a conclusion of findings from daily returns and value development, during the period of 1/2019-12/2020 all the introduced variables had abnormal changes in their value development. Most of the abnormal changes took place in March 2020 when Covid-19 had the greatest impact on financial markets. All the variables had a significant drop in their value during that time, except Tether. Tether managed to retain its value almost throughout the whole period. The greatest loss of value was experienced by the United States' five-year loan, which was not able to bounce back after the Covid-19 turmoil. The greatest improvement in value was experienced by Bitcoin and Ethereum, both of which were able to

bounce back in a short period of time. Additionally, their values were in much higher levels at the end of the period than it was before the Covid-19 crisis.

All variables in this study experienced long-term trend changes in their volatility after the Covid-19 outbreak. For Tether, the change made it less volatile, but for other examined assets, the Covid-19 turmoil made their long-term volatilities bigger. In addition, during the outbreak, variables other than Tether had significant raise in the volatility for a short period of time.

4.1.2 Descriptive statistics and unit root tests

Table 2 provides descriptive statistics for all the assets examined. There are clear differences between the assets examined. The first difference relates to the mean returns during the examination period. Bitcoin and Ethereum have been able to generate the highest daily returns, while the lowest average daily returns have been generated by Tether and DAX index. Of the assets, the five-year German and US government bonds are not fully comparable with the others because their yield is based on the interest received from them and not on the daily returns. Thus, the statistics in Table 2 for these variables represent the average over the reference period. However, the only clearly negative return came from a German five-year government bond.

By comparing the standard deviations, it becomes visible that Bitcoin and Ethereum stand out again from other assets. The standard deviation of these two assets is significantly higher and thus the volatility is higher than the others', and as a result of which their price has fluctuated significantly during the period considered. Also, their one-day maximum and minimum change is clearly higher than in others.

Table 2 Descriptive statistics for the logarithmic returns and descriptive statistics for returns of governmental bonds

	Bitcoin	Ethereum	Tether	SP500	DAX	Gold	US5Y	GER5Y
No. of observations	492	492	492	492	492	492	492	492
Mean	0.40%	0.34%	-0.0003%	0.081%	0.053%	0.069%	1.24%	-0.63%
Std. Dev.	4.33	5.35	0.26	1.66	1.63	1.09	0.82	0.15
Min.	-31.59%	-42.36%	-2.14%	-12.77%	-13.05%	-5.11%	0.19%	0.99%
Max.	24.99%	20.01%	2.01%	8.97%	10.41%	5.61%	2.63%	-0.28
Kurtosis	8.8	9.05	26.95	14.75	13.47	5.33	-1.49	-0.37
Skewness	-0.25	-0.84	-0.77	-1.07	-1.02	-0.22	0.1	0.32
Jarque-Bera	1607.4	1751.2	15044	4591	3833.6	593.1	45.96	11.1
Arch-Test	16.17	15.99	149.37	211.85	127.59	69.3	478.2	461.4

Before forming the model for correlations, unit root tests are conducted. The purpose of root tests is to determine the stationarity of the time series used in the study. The results of the unit root tests are reported in Table 3. Augmented Dickey Fuller and Phillips-Perron tests are used in the unit root tests. Based on

the tests all of the asset returns are non-stationary, except governmental bonds. This causes some unreliability in the results of the study.

Table 3 Unit root tests

Asset Tested	ADF-Test	Phillips-Perron-Test
Bitcoin	-7.7404***	-489.08***
Ethereum	-7.5458***	-488.06***
Tether	-9.1544***	-513.99***
SP500	-7.5175***	-721.1***
DAX	-8.0243***	-541.46***
Gold	-9.9488***	-475.96***
US5Y	-1.5246	-5.9562
GER5Y	-2.5738	-16.645

4.2 DCC-GARCH model

4.2.1 Modelling

Daily returns and timeseries development of examined variables already give some idea of the hedging and safe haven characteristics of the variables against indices, but the aim is to improve this understanding by using the Multivariate Dynamic Conditional Correlation GARCH model. DCC-GARCH model is firstly published by Engle (2002). The DCC-GARCH model is a developed version of Bollerslev constant conditional correlation – model and it seeks to indicate how correlations between different variables evolve over time (Engle, 2002). Correlations are strongly present with variables' hedging characteristics against different assets, as is visible in Baur and Lucey's (2010) discoveries about negative correlation between hedging asset and asset hedged against.

Engle's (2002) DCC GARCH model is formed as follows.

$$H_t = D_t R_t D_t$$

Where H_t denotes a covariance matrix, D_t denotes conditional standard deviations matrix and R_t is a correlation matrix (Engle, 2002). In this model R_t must be a positive definite and Engle (2002) has achieved this by a proxy process which goes as follows:

$$\begin{aligned} Q_t &= \bar{Q} + a(z_{t-1}z'_{t-1} - \bar{Q}) + b(Q_{t-1} - \bar{Q}) \\ &= (1 - a - b)\bar{Q} + az_{t-1}z'_{t-1} + bQ_{t-1} \end{aligned}$$

After the proxy process correlation matrix R_t is obtained by rescaling Q_t:

$$R_t = diag(Q_t)^{-1/2} Q_t diag(Q_t)^{-1/2}$$

These equations above tell how DCC model is formed.

4.2.2 DCC-GARCH results

In this section, the DCC-GARCH models' results are examined closely. To make it easier to understand the results, they are divided into sections. The first section indicates the DCC-correlations between Dax and SP500 in order to clarify the basic idea behind the model. The second section presents the DCC-correlations between examined hedging assets and SP500 index. The third section is about the DCC-correlations between hedging assets and DAX index. Inspections include timeseries figures of DCC-correlations between assets and descriptive statistics of them.

The DCC-timeseries models are created from the daily returns timeseries models, except for German and US government debt as the investment in them is not based on a daily return.

Figure 21 below shows the change in the DCC-rate of the daily returns of the DAX and SP500 indices. It is visible in the figure that the DCC-rate remains at a high level throughout the examined period and thus the use of objects against each other for hedging is inappropriate. However, for the sake of comparing other items, it is essential to acknowledge what a malfunctioning hedge means.

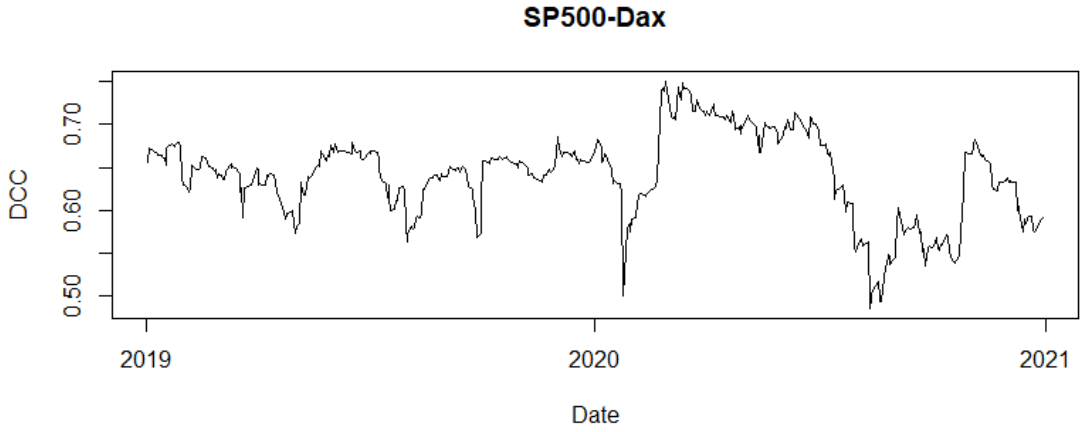

Figure 21 DCC-rate between SP500 and Dax

Table 4 Descriptive statistics of DCC-rates against SP500

Asset	Bitcoin	Ethereum	Tether	US5Y	Gold
Min.	-0.179	-0.159	-0.115	0.061	-0.382
Max.	0.132	0.054	0.066	0.674	0.219
Mean	-0.014	-0.038	-0.028	0.385	-0.038
Std. Dev.	0.043	0.037	0.032	0.104	0.113

Table 4 provides information about DCC-rates between different assets against SP500 index. Bigger values in DCC-rates mean worse hedging characteristics against SP500. Also, bigger volatility DCC-rates between assets examined means worse hedging characteristics for if DCC-rate changes over the time, it is harder for investors to modify their hedge suitable against different risks.

Against SP500, United States five-year loan has the biggest mean and maximum DCC-rate. Ethereum and Gold have the smallest mean DCC-rate, and Gold had the smallest minimum DCC-rate. Standard deviation was smallest in DCC-rate between Tether and SP500 ant it was the biggest between Gold and SP500.

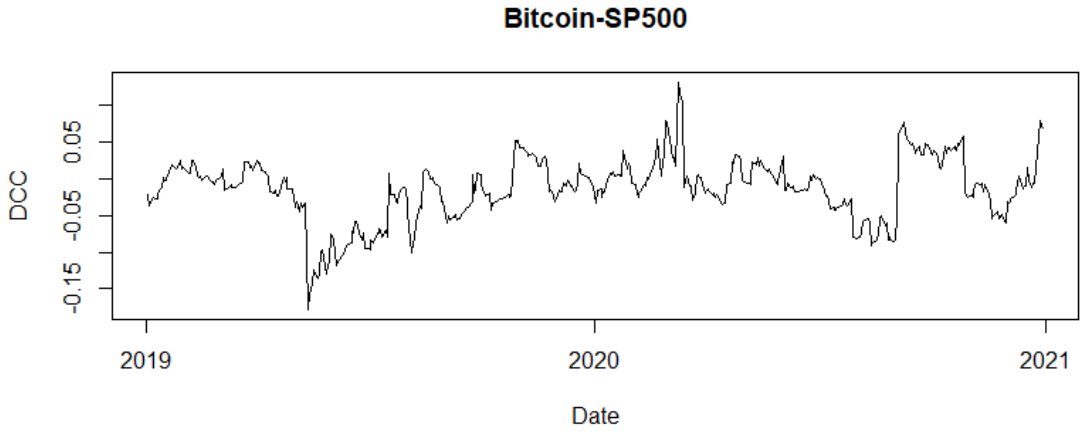

Figure 22 DCC-rate between Bitcoin and SP500

Figure 22 is a timeseries of DCC-rate between Bitcoin and SP500. Volatility of the DCC-rate has been quite small during the inspected period. When the range for DCC-rate is (-0.179 – 0.132), the formation of larger spikes in the statistics is unlikely. There are couple of instances where DCC-rate clearly changes during a short time of period. However, no long-term changes are observed. At the most important time for this study, i.e., 3/2020, a short-term peak is observed in the DCC-rate. The size of the peak is not significant enough to have a greater impact in hedging characteristics of Bitcoin against SP500 index. Nevertheless this spike may cause some harm for safe haven characteristics of Bitcoin, but they are very minor because DCC-rate stays low for the whole period examined.

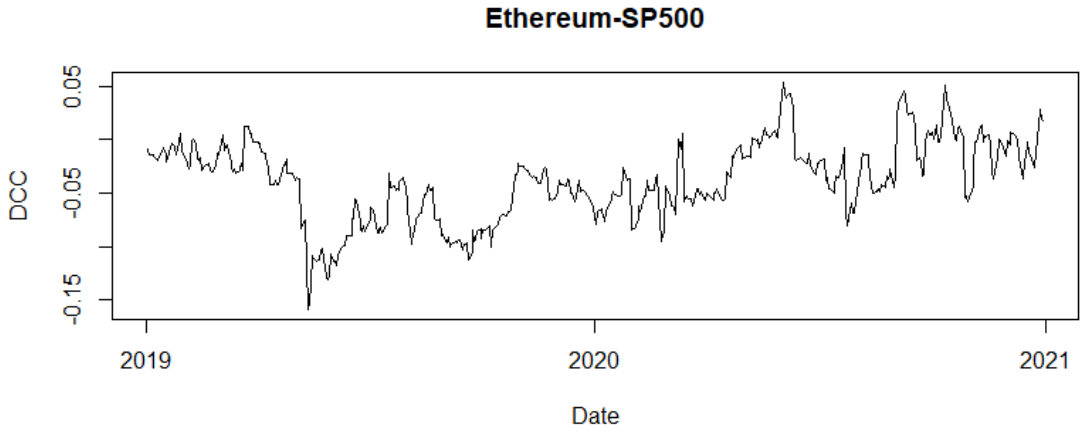

Figure 23 DCC-rate between Ethereum and SP500

Timeseries of DCC-rate between Ethereum and SP500 is available at figure 23. Volatility of DCC-rate is low for the whole period examined, and the mean for it is negative. Therefore, according to the DCC-rate, there might be some usage in hedging against SP500 for Ethereum. After the Covid-19 turmoil there is a slight raise in DCC-rate, but it is not significant in terms of hedging characteristics against SP500. Additionally, there are little to non-short-term peaks in the rates timeseries evolution, so according to DCC-rates, Ethereum is a suitable safe haven against SP500 during the Covid-19 crisis.

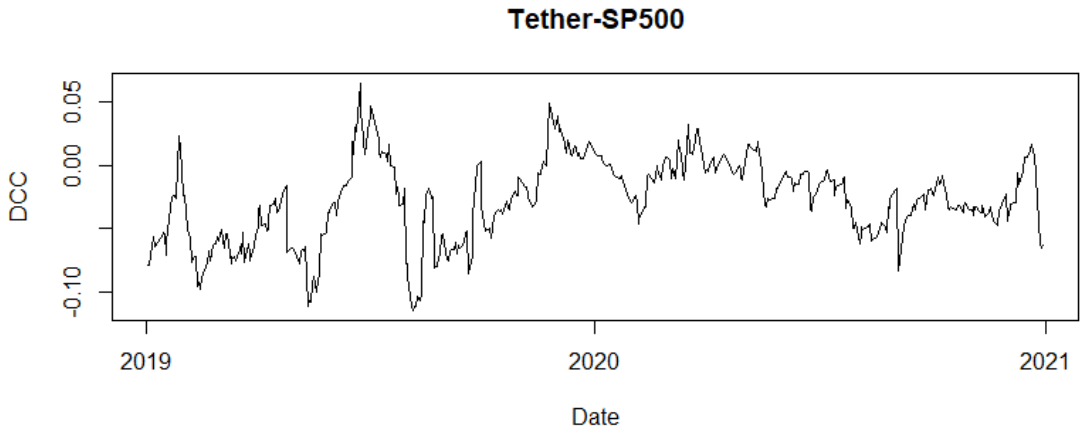

Figure 24 DCC-rate between Tether and SP500

In figure 24 it is visible how the development of DCC-rate between daily returns of Tether and daily returns of SP500 Index is similar with cryptocurrencies and SP500. The volatility of it is quite low and the mean is slightly negative. Additionally, there are no long-term changes in DCC-rate during the examined period. Therefore, Tether can be used in hedging against SP500. According to DCC-rate, Tether is also a suitable safe haven for SP500 because it does not have clear spikes in its timeseries. Especially during the Covid-19 turmoil there are no significant changes.

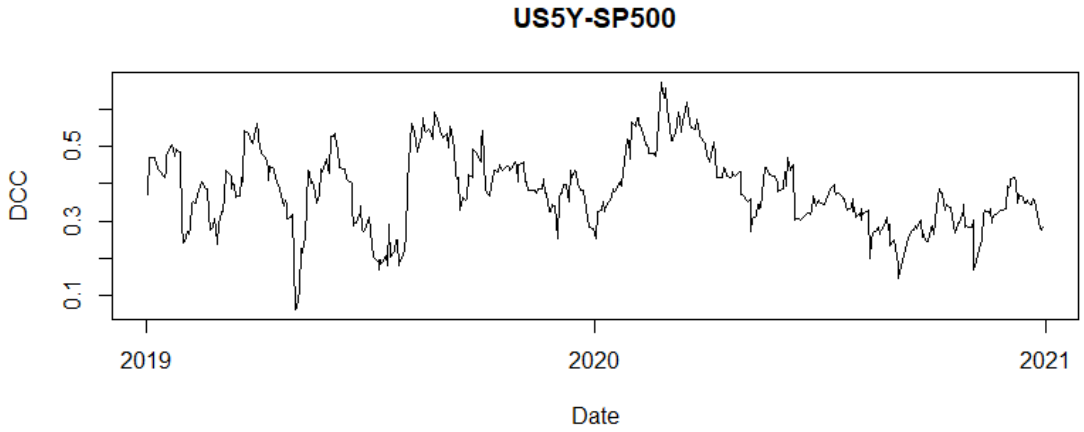

Figure 25 DCC-rate between United States five-year bond and SP500

Figure 25 illustrates the timeseries evolution of the DCC-rate between United States five-year loan returns and daily returns of SP500 index. It can be seen from the figure that the DCC-rate of the US five-year loan and SP500 is clearly different from what it was with cryptocurrencies. Where its volatility was low with cryptocurrencies, it is bigger with the US five-year rate. Additionally, its mean level is higher, and it is on a positive side. After the Covid-19 turmoil, the rate's volatility has decreased a little and the mean declined but it stays on a higher level than cryptocurrencies'. Based on the DCC-rates, the hedging characteristics of US five-year loan against SP500 are worse than cryptocurrencies' equivalents. There are a couple of significant spikes in the figure as well. Therefore, safe haven characteristics of US five-year loan against SP500 are weak or non-existent based on the DCC-rates.

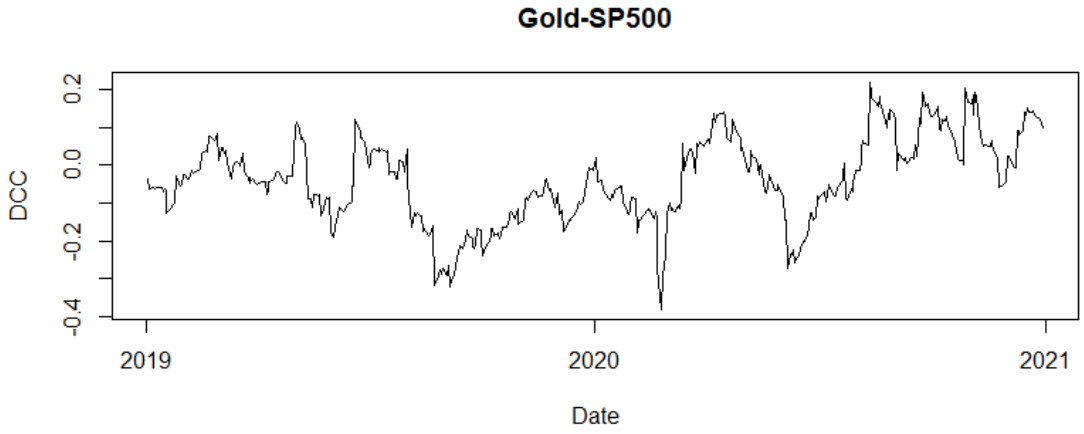

Figure 26 DCC-rate between Gold and SP500

According to figure 26, DCC-rate between daily returns of gold and daily returns of SP500 index has changed during the examined period and it includes a long-term trend change. At the time of the first signs of Covid-19-turmoil, DCC-rate

between these two assets decreased its value to a more negative direction meaning better hedging characteristics for gold. But when the turmoil hit its worst part, the DCC-rate started to rise, meaning worse hedging characteristics against SP500. During the summer of 2020, DCC-rate decreased, but quickly afterwards rose again and stayed in higher levels which are still quite low. Overall, according to DCC-rate, gold offers some hedging characteristics against SP500, but its safe haven properties are shortly lived, as gold's price development begins to follow the development of the SP500 index. It is also worth noting that the increase in the DCC-rate at the end of the examined period also decreases the long-term hedging characteristics as the DCC-rate remains at a high level and does not come back down.

Overall, when it comes to DCC-rates against SP500 index, there are some differences and some similarities between asset classes. DCC-rates between cryptocurrencies' daily returns and SP500 daily returns have smaller standard deviation and lower means than the DCC-rates between daily returns of gold and SP500 or returns from US five-year loan and SP500. Therefore, in hedging characteristics based on DCC-rates, cryptocurrencies offer a better hedge and safe haven against SP500 index than gold or US five-year loan. Lower standard deviation in DCC-rate offers investors less needs for changing their portfolios' positions and smaller value in average means stand for better hedging and safe haven properties because the smaller the value, the more the assets price will move to opposite directions (Baur & Lucey, 2010).

Table 5 Descriptive statistics of DCC-rates against DAX

Asset	Bitcoin	Ethereum	Tether	Gold	Ger5Y
Min.	-0.054	-0.051	-0.047	-0.356	-0.171
Max.	0.185	0.122	0.137	0.309	0.447
Mean	0.025	0.024	0.026	-0.089	0.124
Std. Dev.	0.038	0.031	0.032	0.117	0.051

Table 5 provides descriptive statistics about DCC-rates of hedging assets against DAX index. Even by comparing the means and standard deviations of the values, large differences can be observed between the objects. Clearly the biggest mean for DCC-rate is between Germanys five-year loan and DAX. The smallest mean is between gold and DAX. From the mean, it can be deduced that gold performs best in hedging, but the standard deviation brings its own variable. The significantly larger standard deviation of the DCC-rate between gold and DAX significantly impairs the usability of gold in hedging since bigger standard deviation makes it harder for investors to form a suitable portfolio. Therefore, cryptocurrencies perform the best in hedging against DAX according to mean values and standard deviation in DCC-rates. Although the mean value of the rates with cryptocurrencies is higher, they still offer better options for investors because of the lower standard deviation.

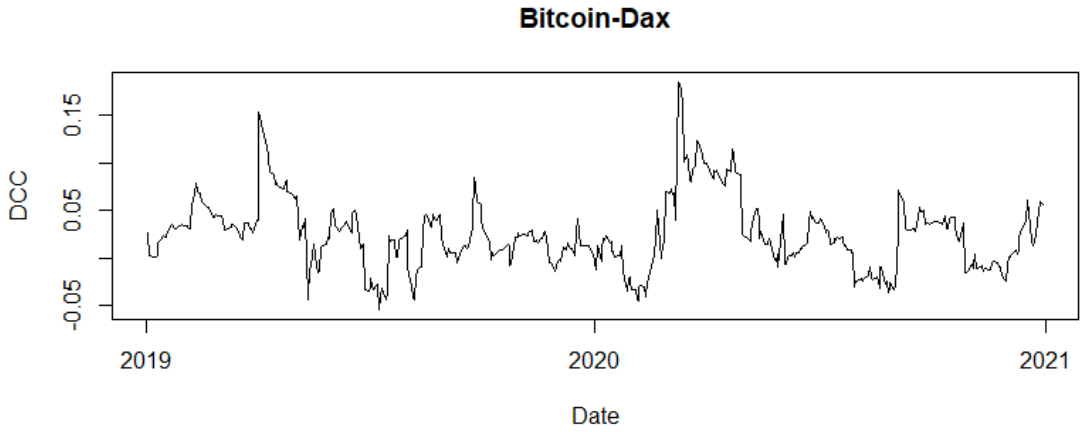

Figure 27 DCC-rate between Bitcoin and DAX

The DCC-rate between Bitcoin and DAX in figure 27 illustrates the following observations. No long-term trend changes are observed in the DCC-rate curve. The curve includes a couple of spikes. The First spike is in the March of 2019 and the Second one is in the march of 2020. The second spike is during the biggest Covid-19 turmoil. After the spikes, the rate decreased back to lower levels.

About hedging and safe haven characteristics, the figure states the following. The range of the rate has been low during the examined period and the mean level is close to zero. Therefore, according to DCC-rate, Bitcoin is a suitable asset for hedging against DAX index. However, the peaks experienced over the examined period slightly weaken Bitcoin's short-term safe haven characteristics. Especially the second spike indicates that Bitcoin did lose some of its safe haven characteristics during the turmoil, but it still managed to maintain a low level in rate overall, and therefore it has no effect on long-term safe haven characteristics. In addition, the spike is shortly lived and therefore hedging characteristics of Bitcoin are not lost in long-term based on DCC-rates. Still the short-term safe haven properties during the Covid-19 turmoil against DAX are questionable.

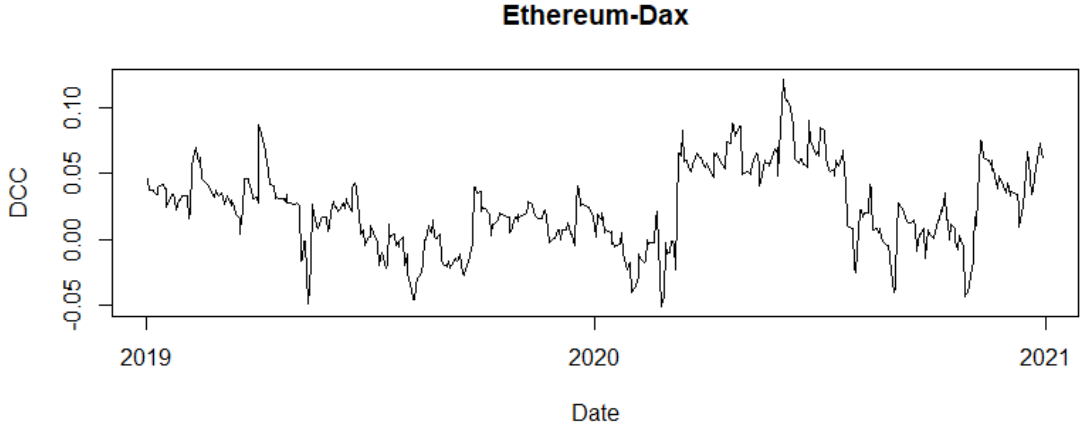

Figure 28 DCC-rate between Ethereum and DAX

Figure 28 illustrates the development of the DCC-rate between Ethereum and DAX index during the examined period. There are no longer-term changes in the curve other than the five months period after the Covid-19 turmoil in March 2020. The value increased momentarily and stayed up for about five months. After the period, the value returned to its lower level and only rose higher again at the end of the period examined.

Overall, the curve is stable when excluding the spike during the Covid-19 turmoil in March 2020. This above-mentioned spike causes some impairments in Ethereum's safe haven characteristics against DAX, but they are not significant since the rate is still low. For short- and long-term hedging against DAX, Ethereum is a suitable asset because the DCC-rate stays near to zero, and it is stable. It is also notable to mention that the figure has some similarities with the Bitcoin equivalent, and therefore Ethereum offers almost the same hedging possibilities against DAX according to DCC-rate.

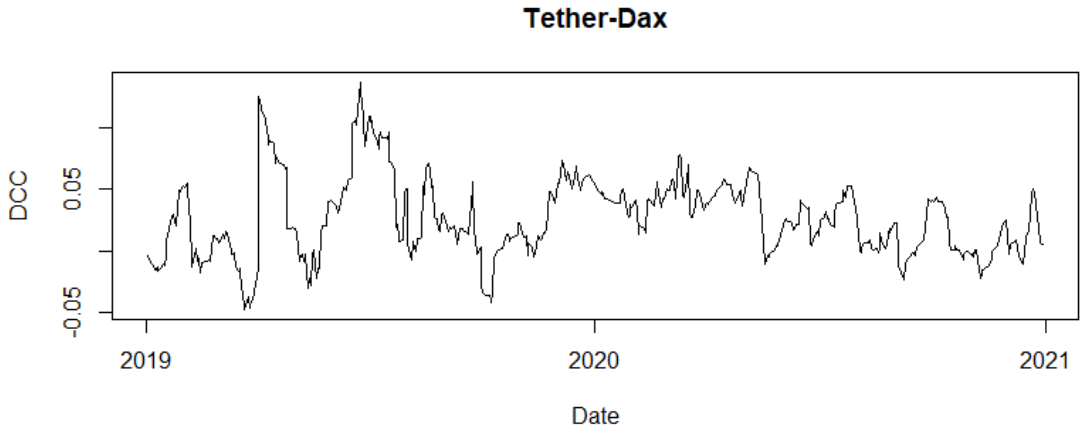

Figure 29 DCC-rate between Tether and DAX

Figure 29 illustrates that there are clear differences in the evolution of the DCC-rate against DAX between stablecoin Tether and other cryptocurrencies. No long-term trend changes can be found in the DCC-rate between Tether and Dax index. The figure has some clear spikes, but they are located in different positions than they are with other cryptocurrencies. Therefore, the reasons for the changes in the rate are different than they are between other cryptocurrencies and DAX.

In the terms of hedging characteristics, a flat and low valued DCC-curve promises favorable in hedging against DAX. According to DCC-rates Tether provides both short- and long-term hedging and safe haven characteristics during the Covid-19 turmoil against DAX, since there are no clear changes during the Covid-19 period. The low level of DCC-rate makes Tether usable in hedging and stable development reduces the need for portfolio changes during the period under review. The lack of a spike in the DCC-rate during March 2020, in turn, increases the usability as a safe haven.

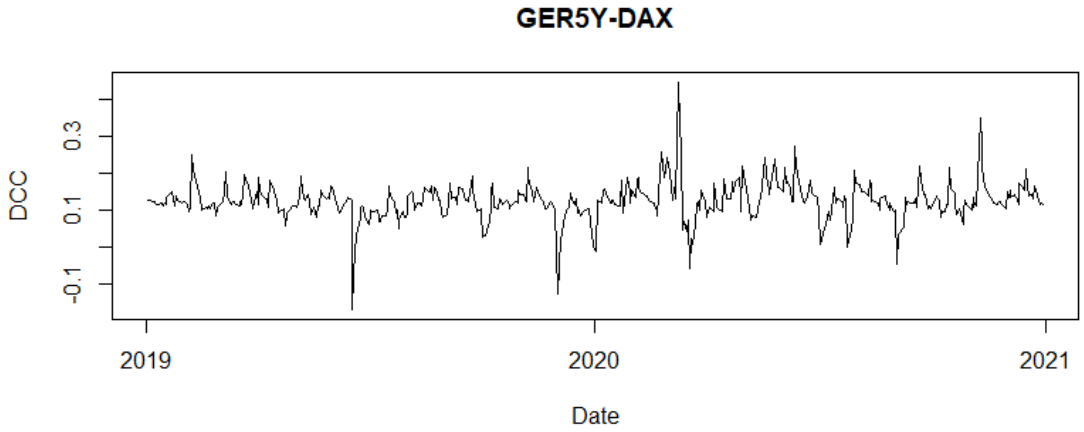

Figure 30 DCC-rate between Germanys five-year bond and DAX

Figure 30 illustrates timeseries evolution of DCC-rate between returns of Germany's five-year bond and daily returns of DAX index. Based on the figure, the development of the DCC-rate between the assets is smooth except for a few spikes. At the most relevant moment for this study, March 2020, one of these peaks can be observed. However, after the peak, no long-term trend changes in the DCC-rate evolution are observed.

Figure 30 describes the following about the hedging characteristics of Germanys five-year loan against DAX. The low DCC-rate allows Germany's five-year loan to be used to hedge against DAX. The steady development of DCC-rate, in turn, means little need for portfolio changes during the review period. Therefore, Germany's five-year loan is suitable asset in short- and long-term hedging against DAX according to DCC-rates. However, for very short-term safe haven purposes, it is not suitable due to the peak caused by the Covid-19 crisis. However, the spike was short-lived, and the value quickly returned to the same level, so therefore it can be used as a long-term safe haven based on the DCC-rate.

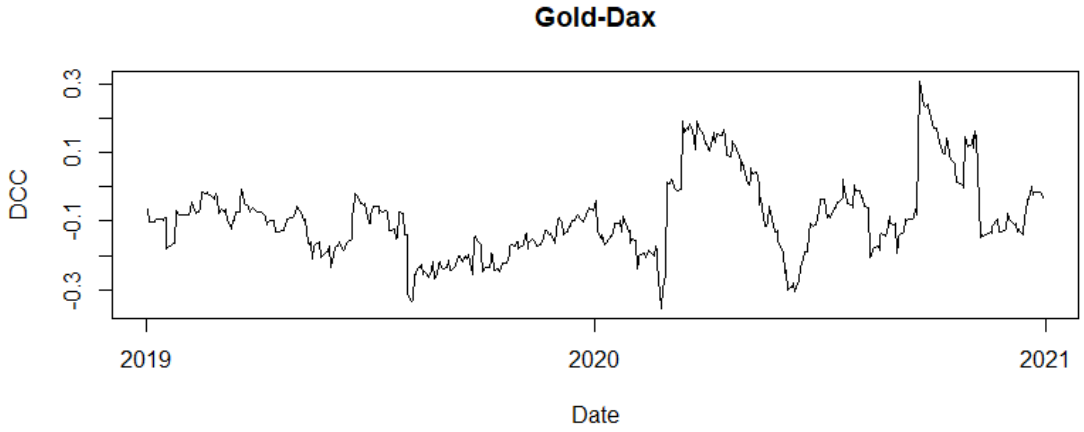

Figure 31 DCC-rate between gold and DAX

From the figure 31, it is visible that the DCC-rate between the daily returns of gold and the daily returns of DAX index differ significantly from the DCC-rates between other investments. The DCC-rate between the daily returns of gold and the daily returns of DAX remained fairly stable and low during the period until March 2020. Then the Covid-19 turmoil struck, and the value began to fluctuate significantly. In the period after March 2020, three clear peaks can be observed from the graph and thus a long-term trend change. DCC-rate between daily returns of gold and DAX index has no longer been able to return to the same stable and low level since the crisis in the market.

The changes visible in figure 31 significantly degrade the hedging and safe haven characteristics of gold against DAX index. A large standard deviation of the DCC-rate indicates a growing need for changes in investors' portfolios to find a suitable hedging ratio. Therefore, based on the DCC-rates, the usability for gold in hedging against DAX is low in both short- and long-term hedging. According to DCC-rates the usability of gold as a short-term safe haven is almost non-existent as it was unable to maintain its DCC-rate at the same level or lower in the face of the turmoil. Additionally, gold cannot be used as a long-term safe haven since the peaks of the DCC-rate observed in figure 31 are not short-lived.

Overall, there are some similarities with DCC-rates against DAX and SP500 indices. Based on DCC-rates, cryptocurrencies offer the best hedging and safe haven options against DAX as is the case with SP500 as well. The DCC-rates between daily returns of cryptocurrencies and DAX index has smaller standard deviation on average and it also stays on lower levels during the turmoil. In particular, Tether is able to maintain its DCC-rate based hedging and safe haven features almost at the same level for the examined period and thus provide the best option for both short-term and long-term hedging against the DAX index. Based on DCC-rates, gold was the worst hedge against DAX. The long-term trend change observed in the evolution of the DCC-rate between the daily returns of gold and the DAX made the use for gold in hedging almost impossible. A large fluctuation in the DCC-rates means a constant change in portfolios' ratios and an increase in rate during a turmoil means a poorly functioning safe haven.

5 RESULTS AND ANALYSIS

Assessing hedging properties is not a simple task as there is no unambiguous answer to it. Because of this, the results of this study are a combination of the assets timeseries evolution, daily returns and DCC-GARCH rates. Based on timeseries of assets' price quotations examined in this study, all the assets are suitable in hedging against SP500 and DAX indices in their own way. Two of the greatest cryptocurrencies on the markets, Bitcoin and Ethereum, offer investors the opportunity of large increases in value and thus they also act as a long-term hedge. For example, an investor has a DAX weighted portfolio with a value of € 10,000 at the beginning of the review period. 10% of the portfolio is invested in Ethereum for hedging the stock market related price risks. The value of this stake in Ethereum is approximately € 5250 at the end of the review period. Therefore, Ethereum as a hedge has generated a significant amount of additional capital for the investor. This example calculation does not consider any trading costs, but there is a significant increase in the value of the portfolio. Understanding the hedging properties of Ethereum and Bitcoin is greatly facilitated by comparing them to government bonds. If in the above-mentioned example calculation, a 10% share is invested in a German 5-year government bond. This would cause a decrease in the value of the investor's portfolio, as the value of the hedge would be about € 990 at the end of the review period. This amount is significantly less than the amount resulting from the use of Ethereum as hedge.

The third cryptocurrency Tether, on the other hand, kept its prices stable throughout the review period, so that investors would not lose their funds in the face of crises. The timeseries development of the price of gold was also stable and upward throughout the period under review and thus, as a hedge in the investment portfolio, it would have generated more funds for the investor. Based on time series, government bonds are the worst performing hedging tools against indices. The five-year German government debt, which remained negative throughout the period under review, would have resulted in continued costs for the investor's portfolio. The yields offered by the corresponding US bond are also weak compared to those of the more successful cryptocurrencies. However, when comparing safe haven properties, the situation is different. There is no major collapse in Tether and government bond price developments in March 2020 following the outbreak of the Covid-19 crisis. Therefore, these three assets are better suitable in short-term safe haven purposes against DAX and SP500 than other examined assets do.

Comparing daily returns of the assets is also an essential part of estimating the best performing hedge. Large daily price fluctuations can mean constant changes in the value of an investor's portfolio, and this can cause problems in liquidation, for example. Tether stands out clearly from others in this area. Its daily price changes are only a marginal part of its counterparts, and for this, Tether is the best suited hedge against DAX and SP500.

The third variable compared in this study is the DCC-rates between the assets. There are clear differences between the assets in terms of DCC-rates against DAX and SP500 indices. Cryptocurrencies performed clearly better than other asset classes in this area. The DCC-rates of cryptocurrencies remained, on average, lower than others and in addition, had a smaller standard deviation. In particular, Tether stood out favorable since there were no noticeable major changes in its DCC-rate in the face of the turmoil, nor any other long-term trend changes. Bitcoin and Ethereum also fared well when comparing DCC-rates, but there were spikes in the evolution of their curves that weaken their usability as a safe haven during turmoil.

By combining the three above-mentioned areas, it is possible to form a clear picture of the functionality of cryptocurrencies as a hedge as well as a safe haven against DAX or SP500. All of the three examined cryptocurrencies were suitable in hedging during the examined period. Bitcoin and Ethereum offer enormous raise in price level and Tether offer stability in price. Therefore, depending on the investor's preferences, all three are suitable for hedging in their own way. Differences emerge when investigating the usability as short-term safe havens. Out of the compared cryptocurrencies, only Tether was able to retain its value during the turmoil caused by Covid-19. Therefore, it is a better asset than the others for short-term safe haven purposes. In turn, other cryptocurrencies are suitable as long-term safe havens, as their values returned relatively quickly to pre-turmoil levels.

When compared to other asset classes, it can be observed that cryptocurrencies perform better in almost everything. Of the cryptocurrencies, Tether offers more stable price development than any other asset considered, and therefore offers the best short-term safe haven. The other cryptocurrencies involved, on the other hand, offer the best long-term safe haven features, as their appreciation has been steady, and pre-turmoil values were quickly restored. Cryptocurrencies also offer the best long-term hedging since their value development increases the overall value of an investor's portfolio. For example, holding government bonds can cause impairment to an investor's portfolio, because interest rates are at a negative level. According to this study, out of other investments, gold has a clear usability for hedging purposes, but the usability is not as high level as it is with cryptocurrencies. As a short-term safe haven, it performed better than Bitcoin or Ethereum, but lost to Tether. In turn, as a long-term safe haven, it will lose to Bitcoin and Ethereum since its post-crisis value development has not been as upward.

Overall, when finding the best performing hedging tool during the Covid-19 turmoil one must see the entirety and state that Bitcoin and Ethereum work best as a hedge as well as a long-term safe haven against DAX and SP500 indices. In the short term, the use of Bitcoin and Ethereum in hedging should not be considered as their price development is very volatile. Tether, on the other hand, works best as a short-term safe haven due to the evolution of its price development.

6 CONCLUSIONS

The aim of the present master's thesis was to discover a hedging tool that operates the best during Covid-19 crisis, as well as to look at the properties of three most actively traded cryptocurrencies in hedging against two major market indices. For an investor, who uses cryptocurrencies in hedging, it is helpful to understand what cryptocurrencies are, how they work, and a little bit of history behind them. These questions were answered based on previous literature. According to Corbet et al. (2019), cryptocurrencies are distributed digital currencies using blockchain technology, and in 2008, the first cryptocurrency called Bitcoin was published. The main difference between cryptocurrencies and traditional currencies is that cryptocurrencies use a peer-to-peer network to verify transfers, whereas traditional currency transfers are verified by a central unit, such as a central bank (Nakamoto, 2008).

The purpose of the present thesis was to focus more on the economic features of cryptocurrencies, and more specifically on the hedging and safe haven features, rather than on their technical implementation. A review of the previous literature revealed that the hedging properties of cryptocurrencies are strongly related to the time, model, and assets of the study. For example, based on the findings of Shahzad et al. (2020), Bitcoin is suitable in hedging against different stock markets. Meanwhile Kliber et al. (2019) state that Bitcoin has only weak hedging characteristics against different stock markets worldwide. There was also mixed evidence of the hedging usability of other assets examined in the thesis, so it was impossible to draw uniform conclusions from the existing literature.

The aim of the present empirical study made was to find the best hedge and safe haven during the market turmoil caused by Covid-19, using timeseries analyses and the DCC-GARCH model. Based on these two methods, Tether offered the best short-term safe haven properties during the examination period. It was able to maintain its price stable during the whole period. On long-term, best hedging and safe haven characteristics against DAX and SP500 indices were offered by Bitcoin and Ethereum, because their DCC-GARCH rate was able to stay low during the examination period, and they face a significant rise in value towards to the end of the period. The worst hedging characteristics against DAX and SP500 indices was offered by governmental bonds. Unites States and Germany's five-year loan rates were on a low level during the whole examination period, and they went even lower towards the end. In addition, Covid-19 turmoil made them more volatile and therefore worse in hedging use.

The present thesis succeeded in finding answers to the research questions presented in the introduction.

RQ1. What are the hedging capabilities of a small set of most actively traded cryptocurrencies? Based on the literature review and the present study made, there are clear usability for cryptocurrencies in hedging against stock market related risks. The different characteristics of individual cryptocurrencies provide

opportunities for hedging in the face of different downfalls or turmoil. Tether's stablecoin features provide protection in the event of rapid collapses. The long-term rise in the price of Ethereum and Bitcoin, in turn, offers the investor a profitable alternative to both diversification and hedging against the decline in the value of stock indices.

RQ2. Which cryptocurrency performed the best as a hedging tool during Covid-19 crisis? The present thesis compared three different asset classes. Based on a study and a review of the literature, in general, the best hedging characteristics against market indices during the Covid-19 turmoil were provided by Bitcoin and Ethereum. The significant rise in the price of the aforementioned cryptocurrencies is one of the biggest factors in assessing their hedging characteristics. Thus, the results of the study cannot be applied outside of the studied time period since the increase in value may not be continuous.

Future studies could prospectively investigate at the use of cryptocurrencies in hedging in a broader term, as in a short-term, their prices may fluctuate significantly and thus provide unreliable results on their characteristics.

REFERENCES

Aggarwal, S. & Kumar, N. 2021. Chapter Twelve – Cryptocurrencies. *Advances in Computers 121* (2021) 227-266

Alexander, C. & Heck, D.F. 2020. Price discovery in Bitcoin: The impact of unregulated markets. *Journal of Financial Stability 50* (2020)

Ante, L., Fiedler, I. & Strehle, E. 2020. The influence of stablecoin issuances on cryptocurrency markets. *Finance Research Letters* (2020) Article in press

Arouri, M.E.H., Lahiani, A. & Nguyen, D.K. 2015 World gold prices and stock returns in China: Insights for hedging and diversification strategies. *Economic Modelling 44* (2015) 273-282

Ashraf, B.N. 2020. Stock markets' reaction to COVID-19: Cases or fatalities? *Research in International Business and Finance 54* (2020)

Bahmani-Oskoee, M., Ghodsi, S.H. & Hadzic, M. 2020. Asymmetric causality between stock returns and usual hedges: An industry-level analysis. *The Journal of Economic Asymmetries 21* (2020)

Basher, S.A. & Sadorsky, P. 2016. Hedging emerging market stock prices with oil, gold, VIX, and bonds: A comparison between DCC, ADCC and GO-GARCH. *Energy Economics 54* (2016) 235-247

Baur, D.G & Hoang, L.T. 2021. A crypto safe haven against Bitcoin. *Finance Research Letters* 38 (2021)

Baur, D.G. & Lucey, B.M. 2010. Is Gold a Hedge or a Safe Haven? An Analysis of Stocks, Bonds and Gold. *Financial Review 45* (2010)

Baur, D.G. & McDermott, T.K. 2010. Is gold a safe haven? International evidence. *Journal of Banking & Finance 34* (2010) 1886-1898

Beckmann, J., Berger, T. & Czudaj, R. 2015. Does gold act as a hedge or a safe haven for stocks? A smooth transition approach. *Economic Modelling* 48 (2015) 16-24

Beneki, C., Koulis, A., Kyriazis, N. & Papadamou, S. 2019. Investigating volatility transmission and hedging properties between Bitcoin and Ethereum. *Research in International Business and Finance* 48 (2019) 219-227

Bonneau, J., Miller, A., Clark, J., Narayanan, A., Kroll, J. A. & Felten, E. W. 2015. SoK: Research perspectives and challenges for bitcoin and cryptocurrencies. *IEEE Symposium on Security and Privacy.* 104-121.

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? *Finance Research Letters* 20 (2017) 192-198.

Bouri, E., Shahzad, S.J.H., Roubaud, D., Kristoufek, L. & Lucey, B. 2020. Bitcoin, gold, and commodities as safe havens for stocks: New insight through wavelet analysis. *The Quarterly Review of Economics and Finance* 77 (2020) 156-164.

Bouri, E., Shahzad, S.J.H. & Roubaud, D. 2020. Cryptocurrencies as hedges and safe-havens for US equity sectors. *The Quarterly Review of Economics and Finance* 75 (2020) 294–307.

Böhme, R., Christin, N., Edelman, B. & Moore, T. 2015. Bitcoin: Economics, technology, and governance. *The Journal of Economic Perspectives*, 29(2), 213-238.

Cagli, E.C. 2019. Explosive behavior in the prices of Bitcoin and altcoins. *Finance Research Letters* 29 (2019) 398-403.

Chan, W.H., Le, M. & Wu, Y.W., 2019. Holding Bitcoin longer: The dynamic hedging abilities of Bitcoin. *The Quarterly Review of Economics and Finance 71* (2019) 107–113

Charfeddine, L., Benglagha, N. & Maouchi, Y. 2020. Investigating the dynamic relationship between cryptocurrencies and conventional assets: Implications for financial investors. *Economic Modelling 85* (2020) 198-217.

Cheah, E-T. & Fry, J. 2015. Speculative bubbles in Bitcoin markets? An empirical investigation into the fundamental value of Bitcoin. *Economic Letters 130* (2015) 32-36

Cheema, M.A., Faff, R.W. & Szulczuk, K. 2020. The 2008 Global Financial Crisis and COVID-19 Pandemic: How Safe are the Safe Haven Assets? *Covid Economics, Vetted and Real-Time Papers 34* (2020) 88-115

Ciaian, P., Rajcaniova, M. & Kancs, d'A. 2015. The economics of BitCoin price formation. *Applied Economics 48* (2016) 1799-1815

Ciaian, P., Rajcaniova, M. & Kancs, d'A. 2018. Virtual relationships: Short- and long-run evidence from BitCoin and altcoin markets. *Journal of International Financial Markets, Institutions and Money 52* (2018) 173-195

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 (2013) 202-211

Coindance, 2021. Cryptocurrencies by Market Cap (historical) Summary retriewed 21.3.2021 from https://coin.dance/stats/marketcaphistorical

Conlon, T., Corbet, S. & McGee, R.J. 2020. Are cryptocurrencies a safe haven for equity markets? An international perspective from the COVID-19 pandemic. *Research in International Business and Finance 54* (2020)

Corbet, S., Lucey, B., Peat, M. & Vigne, S. 2018. Bitcoin Futures—What use are they? *Economic Letters 172* (2018) 23-27

Corbet, S., Lucey, B., Urquhart, A. & Yarovaya, L. 2019. Cryptocurrencies as a financial asset: A systematic analysis. *International Review of Financial Analysis 62* (2019) 182–199

Crosby, M., Nachiappan, Pattanayak, P., Verma, S. & Kalyanaraman, V. 2016. BlockChain technology: Beyond bitcoin. *Applied Innovation review*, Issue No. 2

Das, D., Le Roux, C.L., Jana, R.K. & Dutta, A. 2020. Does Bitcoin hedge crude oil implied volatility and structural shocks? A comparison with gold, commodity and the US Dollar. *Finance Research Letters* 36 (2020)

Dee, J., Li, L. & Zheng, Z. 2013. Is gold a hedge or a safe haven? Evidence from inflation and stock market. *International Journal of Development and Sustainability 2* (2013) 12-27

Dicle M.F & Levendis, J. 2017. Hedging market volatility with gold. *Quantitative Finance and Economics 1* (2017) 253-271

Dyhrberg, A.H. 2016. Hedging capabilities of bitcoin. Is it the virtual gold? *Finance Research Letters* 16 (2016) 139–144.

Easley, D., O'Hara, M. & Basu, S. 2019. From mining to markets: The evolution of bitcoin transaction fees. *Journal of Financial Economics* 134 (2019) 91–109

Engle, R. 2002. Dynamic Conditional Correlation: A Simple Class of Multivariate Generalized Autoregressive Conditional Heteroskedasticity Models. *Journal of Business & Economic Statistics* 20 (2002) 339-350

Ethereum 2021. What is Ethereum? Retriewef 11.4.21 from https://ethereum.org/en/what-is-ethereum/

European Central Bank 2018. What is bitcoin? Retriewed 4.12.20 from *https://www.ecb.europa.eu/explainers/tell-me/html/what-is-bitcoin.en.html*

Finnish Financial Supervisory Authority 2019. What do the terms virtual currency, cryptocurrency, crypto asset, ICO and wallet service mean? Retriewed 4.12.20 from *https://www.finanssivalvonta.fi/en/Consumer-protection/questions-and-answers/virtual-currencies/*

Garcia-Jorcano, L. & Benito, S. 2020. Studying the properties of the Bitcoin as a diversifying and hedging asset through a copula analysis: Constant and time-varying. *Research in International Business and Finance* 54 (2020)

Gupta, R., Subramaniam, S., Bouri, E. & Ji, Q. 2021. Infectious disease-related uncertainty and the safe-haven characteristic of US treasury securities. *International Review of Economics & Finance 71* (2021) 289-298

Habib, M.M. & Stracca, L. 2015. Is There a Global Safe Haven? *International Finance 18* (2015)

Hayes, A. 2019. Dotcom Bubble. Retriewed 6.12.2020 from: https://www.investopedia.com/terms/d/dotcom-bubble.asp

Hayes, A.S. 2017. Cryptocurrency value formation: An empirical study leading to a cost of production model for valuing bitcoin. *Telematics and Informatics 34 issue 7* (2017) 1308-1321

He, Z., O'Connor, F. & Thijssen, J. 2018. Is gold a Sometime Safe Haven or an Always Hedge for equity investors? A Markov-Switching CAPM approach for US and UK stock indices. *International Review of Financial Analysis 60* (2018) 30-37

Hood, M. & Malik, F. 2013. Is gold the best hedge and a safe haven under changing stock market volatility? *Review of Financial Economics 22* (2013) 47-52

Hsu, C-H., Lee, H-C. & Lien, D. 2020. Stock market uncertainty, volatility connectedness of financial institutions, and stock-bond return correlations. *International Review of Economics and Finance 70* (2020) 600-621

Hui, C-H., Lo, C-F., Chau, P-H. & Wong, A. 2020. Does Bitcoin behave as a currency?: A standard monetary model approach. *International Review of Financial Analysis 70* (2020)

Huynh, T.L.D., Nasir, M.A., Vo, X.V. & Nguyen, T.T. 2020. "Small things matter most": The spillover effects in the cryptocurrency market and gold as a

silver bullet. *The North American Journal of Economics and Finance* 54 (2020)

Investing.com 2021a. All Cryptocurrencies. Retriewed 10.3.2020 from: https://www.investing.com/crypto/currencies

Investing.com 2021b. DAX. Retriewed 13.3.2021 from: https://fi.investing.com/indices/germany-30-historical-data

Junttila, J., Pesonen, J. & Raatikainen, J. 2018. Commodity market based hedging against stock market risk in times of financial crisis: The case of crude oil and gold. *Journal of International Financial Markets, Institutions and Money* 56 (2018) 255-280

Kenton, W. 2019. What was the subprime meltdown. Retriewed 6.12.2020 from: https://www.investopedia.com/terms/s/subprime-meltdown.asp

Kenton, W. & Scott, G. 2020 Financial Crisis. Retriewed 6.12.2020 from https://www.investopedia.com/terms/f/financial-crisis.asp

Kliber, A., Marszalek, P., Musialkowska, I., & Świerczyńska, K. 2019. Bitcoin: Safe haven, hedge or diversifier? Perception of bitcoin in the context of a country's economic situation — A stochastic volatility approach. *Physica A: Statistical Mechanics and its Applications 524* (2019) 246-257.

Kopyl, K.A. & Lee, J.B-T. 2016. How safe are the safe haven assets? *Financial Markets and Portfolio Management 30* (2016) 453-482.

Kristoufek, L. 2015. What Are the Main Drivers of the Bitcoin Price? Evidence from Wavelet Coherence Analysis. *PLoS One* 10 (2015)

Kristoufek, L. 2021. Tethered, or Untethered? On the interplay between stablecoins and major cryptoassets. *Finance Research Letters* (2021)

Kurka, J. 2019. Do cryptocurrencies and traditional asset classes influence each other? *Finance Research Letters* 31 (2019) 38–46.

Lin F-L., Yang, S-Y., Marsh, T. & Chen, Y-F. 2018. Stock and bond return relations and stock market uncertainty: Evidence from wavelet analysis. *International Review of Economics & Finance 55* (2018) 285-294

Liu, W-H. 2018. Are Gold and Government Bond Safe - Haven Assets? An Extremal Quantile Regression Analysis. *International Review of Finance 20* (2018)

Lucey, B.M., Peat, M., Šević, A. & Vigne, S.A. 2019. What is the optimal weight for gold in a portfolio? *Annals of Operations Research* (2019)

Mariana, C.D., Ekaputra, I.A. & Husodo, Z.A. 2020. Are Bitcoin and Ethereum safe-havens for stocks during the COVID-19 pandemic? *Finance Research Letters* (2020) Article in press

Mensi, W., Al-Yahyaee, K.H., Al-Jarrah, I.M.W., Vo, X.V. & Kang, S.H. 2020. Dynamic volatility transmission and portfolio management across major cryptocurrencies: Evidence from hourly data. *The North American Journal of Economics and Finance* 54 (2020)

Metcalfe, B. 2013. Metcalfe's Law after 40 Years of Ethernet. *Computer* 46 (2013) 26-31

Nadler, P. & Guo, Y. 2020. The fair value of a token: How do markets price cryptocurrencies? *Research in International Business and Finance 52* (2020)

Nakamoto, S. 2008. Bitcoin: A Peer-to-Peer Electronic Cash System

Nguyen, Q.N., Bedoui, R., Majdoub, N., Guesmi, K. & Chevellier, J. 2020. Hedging and safe-haven characteristics of Gold against currencies: An investigation based on multivariate dynamic copula theory. Resources Policy 68 (2020)

Pengfei, W., Wei, Z., Xiao, L. & Dehua, S. 2019. Is cryptocurrency a hedge or a safe haven for international indices? A comprehensive and dynamic perspective. *Finance Research Letters* 31 (2019) 1–18

Peterson, T. 2017. Metcalfe's Law as a Model for Bitcoin's Value. *Alternative Investment Analyst Review* 7 (2018) 9-18

Philippas, D., Rjiba, H., Guesmi, K. & Goutte, S. 2019. Media attention and Bitcoin prices. *Finance Research Letters* 30 (2019) 37-43

Reboredo, J.C. 2013. Is gold a safe haven or a hedge for the US dollar? Implications for risk management. *Journal of Banking & Finance* 37 (2013) 2665-2676

Shahzad, S.J.H., Bouri, E., Roubaud, D. & Kristoufek, L. 2020. Safe haven, hedge and diversification for G7 stock markets: Gold versus bitcoin. *Economic Modelling 87* (2020) 212–224

Thampanya, N. Nasir, M.A. & Huynh, T.L.D. 2020. Asymmetric correlation and hedging effectiveness of gold & cryptocurrencies: From pre-industrial to the 4th industrial revolution. *Technological Forecasting and Social Change 159* (2020)

Vliet, B.V. 2018. An alternative model of Metcalfe's Law for valuing Bitcoin. *Economic Letters 165* (2018) 70-72

Wang, G-J., Ma, X-Y., & Wu, H-Y. 2020. Are stablecoins truly diversifiers, hedges, or safe havens against traditional cryptocurrencies as their name suggests? *Research in International Business and Finance* 54 (2020)

Wang, G., Tang, Y., Xie, C. & Chen, S. 2019. Is bitcoin a safe haven or a hedging asset? Evidence from China. *Journal of Management Science and Engineering 4* (2019) 173-188

Wu, S., Tong, M., Yang, Z. & Derbali, A. 2019. Does gold or Bitcoin hedge economic policy uncertainty? *Finance Research Letters* 31 (2019) 171–178

Xu, L. 2020. Stock Return and the COVID-19 pandemic: Evidence from Canada and the US. Finance Research Letters Article in press

Zhang, Y., Wang, M., Xiong, X. & Zou, G. 2020. Volatility spillovers between stock, bond, oil, and gold with portfolio implications: Evidence from China. *Finance Research Letters* (2020) Article in press