Teemu Pösö

Hedging US stock markets in wake of COVID-19 pandemic

Gold, Oil, Bitcoin and Bonds

School of Accounting and Finance
Master's thesis in Finance
Master's Degree Programme in Finance

Vaasa 2023

UNIVERSITY OF VAASA
School of Accounting and Finance
Author: Teemu Pösö
Title of the Thesis: Hedging US stock markets in wake of COVID-19 pandemic : Gold, Oil, Bitcoin and Bonds
Degree: Master of Science in Economics and Business Administration
Programme: Finance
Supervisor: Janne Äijö
Year: 2023 **Sivumäärä:** 66

ABSTRACT:
The purpose of this pro gradu -study is to examine widely regarded hedging assets against S&P 500 stock index during the COVID-19 pandemic. The motivation to study these assets relies on previous literature and unique market conditions of COVID-19 pandemic for markets. Flight-to-quality is often observed during crisis periods when there is turmoil and distress in financial markets. Increased uncertainty drives investors to become more risk-averse and allocate capital in more stable asset classes. Previous literature has indicated that commodities, government bonds and bitcoin could benefit from such phenomenon. Additionally, by pre-emptively allocating portfolio capital to such assets investors could possibly effectively hedge potential losses of one asset with gains on another assets.

This study follows methodology introduced by Baur and McDermott (2010) to compare different assets hedging and safe-haven performance during the COVID-19 markets. Such retrospective analysis provides effective tool for this thesis to provide insight to support future investing theses during market uncertainty. The focus is to set on the United States as the largest open markets in the world with data running from 1st of January 2020 till 20th of December 2021. The data is first cleaned to represent same trading days as the New York Stock Exchange trading days, after which daily returns are presented in log-format of which bottom 1%, 5% and 10% quantiles are picked with dummy variables. Identical formulas are used for different assets to determinate the effectiveness to limit the volatility during these trading days in order to find out possible safe haven effectiveness and hedging ability.

The obtained results suggest that most of the assets failed to act as safe haven asset during the COVID-19 markets. Only bonds successfully hedged stock market volatility and losses for investors. When compared with previous literature this study does affirm and contradict number of previous studies. These results can be affected by number of factors such as different sample periods and methodological choices. Results do however indicate that U.S. Government bonds with different maturities did act as hedge against S&P 500 stock market index during the sample period. In addition, gold can be regarded as an effective diversifier with S&P 500 stock index.

KEYWORDS: COVID-19, coronavirus, Hedge, Bitcoin, Gold, Oil, Brent, Safe-haven

VAASAN YLIOPISTO
School of Accounting and Finance
Tekijä: Teemu Pösö
Tutkielman nimi: Hedging US stock markets in wake of COVID-19 pandemic: Gold, Oil, Bitcoin and Bonds
Tutkinto: Kauppatieteiden maisteri
Oppiaine: Rahoitus
Työn ohjaaja: Janne Äijö
Valmistumisvuosi: 2023 **Sivumäärä:** 66

TIIVISTELMÄ:
Tämän pro gardu -tutkimuksen tarkoituksena on tarkastella erilaisten suosittujen omaisuusluokkien kykyä suojautua S&P 500 -osakeindeksiä vastaan COVID-19-pandemian aikana. Motivaatio näiden hyödykkeiden tutkimiseen perustuu aikaisempaan kirjallisuuteen ja markkinoiden ainutlaatuisiin COVID-19-pandemian olosuhteisiin. “Flight to quality“ -ilmiö havaitaan markkinoilla usein kriisiaikoina, jolloin rahoitusmarkkinoilla vallitsee kriisitunnelmat ja markkinoilla on epävarmuutta. Lisääntynyt epävarmuus saa sijoittajat karttamaan riskejä ja kohdistamaan pääomaa vakaampiin omaisuusluokkiin. Aikaisempi kirjallisuus on osoittanut, että erilaiset käyttöhyödykkeet, valtion obligaatiot ja bitcoin voisivat hyötyä tällaisesta ilmiöstä. Lisäksi sijoittajat voivat tehokkaasti suojata yhden omaisuuden mahdolliset tappiot toisen omaisuuserän voitoilla jakamalla portfoliopääomaa ennaltaehkäisevästi tällaiseen omaisuuteen.

Tämä tutkimus noudattaa Baurin ja McDermottin (2010) esittämää ja käyttämää metodologiaa vertaillakseen eri omaisuuserien kykyä suojata ja toimia turvasatamana COVID-19-markkinoiden aikana. Tällainen retrospektiivinen analyysi tarjoaa tehokkaan työkalun tälle opinnäytetyölle, joka antaa näkemystä tukemaan tulevia investointeja kun markkinoilla on suurta epävarmuutta. Tutkimuksen painopiste on Yhdysvaltoissa, maailman suurimassa avoimessa markkinoissa, joiden data on haettu ajalta 1.1.2020–20.12.2021. Data puhdistetaan ensin edustamaan samoja kaupankäyntipäiviä New Yorkin pörssin kaupankäyntipäivien kanssa, minkä jälkeen päivittäiset tuotot esitetään log-muodossa, josta alaosan 1%, 5% ja 10% kvantiilit on poimittu dummy-muuttujien avulla. Eri omaisuuserille käytetään identtisiä kaavoja määrittämään tehokkuutta rajoittaa volatiliteettia näinä kaupankäyntipäivinä, jotta saadaan selville mahdollinen kyky suojata pääomaa ja toimia turvasatamana.

Tulokset viittaavat siihen, että suurin osa tutkituista omaisuusluokista eivät toimineet turvasatamana COVID-19-markkinoiden aikana, vain joukkovelkakirjat suojasivat osakemarkkinoiden volatiliteetilta ja rajoittivat sijoittajien tappioita. Verrattuna aikaisempaan kirjallisuuteen tämä tutkimus esittää ristiriitaisia tuloksia aikaisempien tutkimusten kanssa. Näihin tuloksiin voivat vaikuttaa monet tekijät, kuten erilaiset näytejaksot ja metodologiset valinnat. Tulokset osoittavat kuitenkin, että Yhdysvaltain valtion joukkovelkakirjat, joilla on eri maturiteetit, suojasivat S&P 500-osakeindeksiä näytejakson aikana. Lisäksi kultaa voidaan pitää tehokkaana hajottajana S&P 500-osakeindeksillä.

AVAINSANAT: COVID-19, coronavirus, Hedge, Bitcoin, Gold, Oil, Brent, Safe-haven

Contents

Figures

Tables

1 Introduction

COVID-19 pandemic surprised everyone. At the beginning of 2020, stock markets had reached it's all time high with buffet indicator glowing red. The fundamental restriction of limited capital was quickly removed by FED and ECB with intensive actions of bond purchase programs as well as lowering the central banks' interest rate targets to zero. All at once, capital was cheap, and it was available to everybody. The markets did recover quite quickly and did recover from March 2020 crash in record time. The bear market of 2020 was the shortest in history by lasting total of 33 days, compared to average bear market of 302 days since 1920s. The capital was still there freely for everyone to utilize, with FED and ECB buying up corporate and government issued fixed income products, investors flowed stock markets with liquidity (Platt and Carnevali, 2020).

Gold's capabilities to act as safe haven asset, hedge financial turmoil and diversify portfolio are vastly studied throughout financial markets. Current consensus being, that gold can offer benefits for investors during the times of financial turmoil. Studies show, that gold can stabilize financial markets by reducing the losses on developed markets (see: Bauer and McDermott, 2010; Baur and Lucey, 2010; Hood and Malik, 2013; Beckmann et al. 2015). Additionally, gold has been an ultimate hedge against the US dollar throughout its history (Capie et al., 2005).

Bitcoin has gathered a lot of attention from academical studies in recent years. It has been described as "Digital gold", "Gold 2.0" or "New gold". Similarities in attributes such as decentralization, distribution in mining and ownership and limited supply support these descriptions. The early paper to support this analogy was published by Dyhrberg (2016b), in which the term "digital gold" presents itself. By using similar methodology as with earlier studies of gold's ability to hedge Financial Times Stock Index (FTSE) and US dollar, Dyhrberg studies the ability for bitcoin to hedge these markets in limited observation period of July 2010 to May 2015. Results present that bitcoin is uncorrelated with FTSE 100 index and and thus indicates that bitcoin can be used as a substitute for gold in investment portfolio with FTSE 100 -index. The study also finds that the bitcoin can be

used as an hedge against the US dollar in short-term window. As an conclusion, Dyhrberg presents bitcoin as an effective “virtual gold”. However, previous literature has also indicated that diversification benefits diminish during the times of financial turmoil (Campbell et al., 2002).

Unsurprisingly, some studies (see: Bouri et al., 2017a; Conlon et al., 2020; Conlon and McGee, 2020; Grobys, 2021) have implicated just opposite for the bitcoin: bitcoin does not protect but amplifies the losses from stock markets during the extreme market distress. Bouri et al. (2017) present that Bitcoin is only a diversifier and poor hedge against world’s stock indices, based on empirical data and DCC modelling (Engle, 2002) from July 2011 to December 2015. However, Bouri et al. (2017) also notes that diversification benefit from Bitcoin might not be constant over time due to the high volatility and low liquidity of bitcoin markets during the sample period. Conlon et al. (2020) conduct empirical analysis for Bitcoin’s safe haven properties during the COVID-19 crisis by calculating VaR (Value at risk), MVAR (Modified VaR) and CVaR (Conditional VaR) values for downside risk for portfolios consisting of cryptocurrencies and stock market indices. Additionally moving window analysis is considered as an robustness test for these findings. Altogether, Conlon et al. (2020) consider bitcoin to not be a safe haven asset but instead increasing the downside risk for portfolios consisting of any allocation of bitcoin. The only exception is found from emerging market index of CSI 300 (Shanghai stock index). Similarly Conlon and McGee (2020) study the safe haven properties of Bitcoin for US stock index during the initial bear market of COVID-19 with similar discoveries, that Bitcoin increased, not decreased, downside risk exposure for portfolios. Grobys (2021) studies the initial setup of S&P 500’s COVID-19 market crash, gold and Bitcoin markets with dynamic correlation between these assets. Using dynamic correlation between gold and S&P 500 as a control group, Grobys (2021) discovers that bitcoin does not serve as a useful asset for hedging COVID-19 tail risk for S&P 500 stock index. However, Grobys (2021) also notes, that large scale liquidation of Bitcoin positions (from Bitmex cryptocurrency exchange) also factors as an reason for price decline and thus COVID-19 is not singular reason for overall price decline of Bitcoin during the wake of COVID-19.

With disputed claims on Bitcoin's ability to act as an safe haven or hedge, it is beneficial for this study to research the bitcoin's role in the COVID-19 crisis, on weather the bitcoin did act as an safe haven or hedge against the US stock markets. Additional studies have also been published since Dyhrberg (2016b) with number of changes in methodology and portfolio pairs. Bitcoin markets have also developed since May of 2015 with introduction of new instruments such as futures and options. Increasingly, the information on cryptocurrencies has also spread more widely and market capitalization has also increased drastically since 2015. Klein et al. (2018) theories well that during the "flight-to-quality" investors tend to want to lower their portfolio risk. As bitcoin and cryptocurrencies in general have been generally accepted to be more volatile and riskier investments with lack of proper valuation model, it is highly unlikely for this study to accept bitcoin as a valid safe haven during the COVID-19 pandemic.

Thus, we can create our first hypothesis by following the rationale presented by Klein (2018):

> H1: The Bitcoin does present itself as an ineffective hedge against the S&P 500 stock market index during COVID-19.

Gold's ability to hedge different crisis of stock market crisis, currency crisis, fixed income market crisis and other non-financial crisis such as economic uncertainty have been widely studied. Gold's ability to act as an effective hedge against such crisis have been extensive and as such gold has been accepted as one of the best safe haven for time of financial turmoil. COVID-19 however has been one-of-a-kind shock for world's economy and as such studying gold's ability in this context is favourable for academic contribution. Additionally, more recent articles regarding the role of gold during the COVID-19 pandemic have questioned this (Hasan et al., 2021). The argument for these changed properties of gold presented by Cheema et al. (2020) is explained by changed investor confidence for the gold as an asset after the 45% price decrease in between September 2011

and December 2015. Strong academic research background has been however impressive and as such we accept academic consensus on gold's ability to lower portfolio risk.

Following these studies, we can formulate the second hypothesis:

H2: The gold does present itself as an effective hedge against the S&P 500 stock market index during COVID-19.

Theory for the co-movements between oil and stock markets can be explained with asset pricing theory. Asset pricing theory states that prices are formulated based on expected cash-flows. With increase in oil prices, the cost-of-goods for companies should increase as well, resulting in decrease in stock prices. Evidently, decrease in oil-prices should lower the cost of doing business, bolstering the profit margins for companies and thus increase the stock prices. For a oil exporting countries, the effect should be opposite. As oil prices increase, the cash inflow increases which bolsters the country's economic conditions and thus reflect positively into country's stock markets. Jiménez-Rodríguez and Sánchez (2005) find evidence from OECD countries that are oil-importers (such as the United States) suffer from increase in oil prices.

H3: The oil does present itself as an ineffective hedge against the S&P 500 stock market index during COVID-19 market.

Bonds have been used to hedge stock markets for number of years. The correlation between these assets is evident from years of academic studies and financial valuation models. In addition to financial models such as discounted cashflow model's (DCF) and capital asset model's (CAPM) pricing mechanism, bonds are preferred safe haven assets due to overall lower risk profile. Existing literature present bonds as effective hedge against stock markets during the times of financial crisis (Baur and Lucey, 2009).

H4: U.S. Treasure bonds does present itself as a hedge against the S&P 500 stock market index during COVID-19 market.

1.1 Purpose of the study

The purpose of this thesis is to study the safe heaven aspects of the Bitcoin, gold, oil and bonds with S&P 500 stock index during the COVID-19 pandemic. Traditionally, gold has been selected to be a safe haven asset in times of crisis, with different flight-to-safety events, gold has been able to store value during the times of financial turbulence and thus been able to protect the investor's assets. COVID-19 was a different type of crisis, one which was initiated by public health crisis which developed into a financial one after strict restrictions across the globe. Thus, the ability for gold to act in role of safe heaven asset has been put under question while new ones have arisen around the topic of cryptocurrencies to been able to act as "digital gold" as described in earlier studies.

The selection of the Bitcoin was motivated by the dominative role of the Bitcoin in the cryptocurrency market. Bitcoin dominance -index has changed during the pandemic, from high 72% to low 40% axis, tracked by market capitalization. At the same time, the current literature is cantered around the Bitcoin. S&P 500 index was chosen as a counterpart for this thesis by the fact that it is the largest stock market in the world and that it does represent a large market capitalization of US equity markets.

This thesis uses model deployed by Baur (2010) in which the correlation between assets is measured during the times of extreme market stress and include regressors which contain stock returns in q% lower quantile (10%, 5% and 1%). As such, this study aims to expand existing literature on COVID-19 financial crisis and investors' options to hedge stock market crisis during this unique timeframe.

1.2 Structure of the study

This thesis follows the following structure: The introduction part explains the aim of this thesis and presents the hypotheses. The second part introduces different aspects of theoretical background in portfolio theory, risk management, COVID-19, commodity-, cryptocurrency- and US equity- and bond markets. The third part discusses on previous

literature on stock market correlation with different assets. The fourth part covers the data and methodology used in this thesis to study the research questions. In the results, findings are explained and analysed. The last part concludes this thesis and provides topics for future research.

2 Background

2.1 US equity markets and S&P 500

US equity markets are the largest in the world. As presented in figure below, as of 2022, US equity markets in total consisted of 41,6% of global market cap of listed companies.

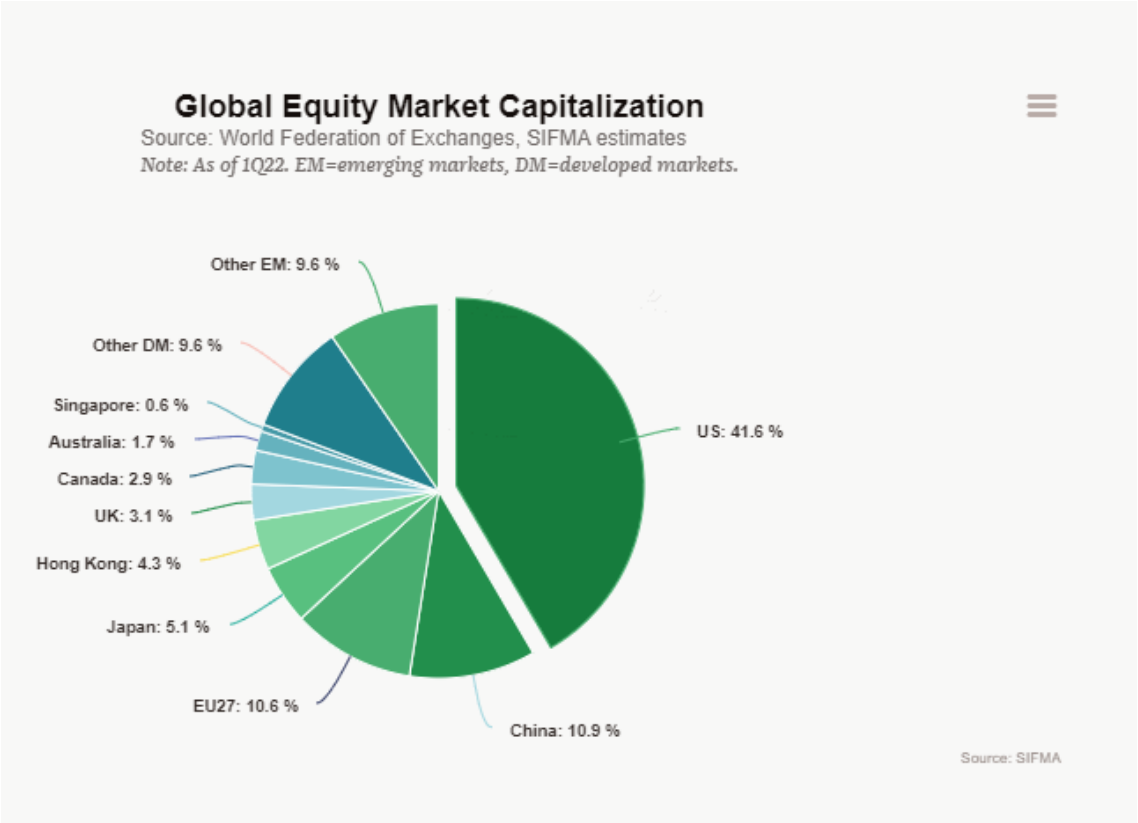


Figure 1 Global equity market capitalization in Q1/2022 (Sifma Research Quarterly 2022)

In addition to this, many companies from different countries double list their stocks in US equity markets. S&P 500 consists of 500 selected companies across the different industries from the New York Stock Exchange (NYSE) -index. Companies are selected based on a number of characters, including the market cap of a company. As such S&P 500 is widely accepted as a valid proxy for the entire US stock market. Companies in the index are closely followed by a large number of financial analysts and investors and as such valuation can be considered accurate and mispricing is rare.

Currently there are in total 11 different sectoral indexes provided by S&P. These indexes consist of US trading stocks in their respective sectoral allocation. Indexes are weighted by market-capitalization. These indexes are float-adjusted quarterly based on market capitalization of each company selected in the index. These rules are applied in every S&P indexes. In addition, there are alternative equal weighted and capped market capitalization weighted alternatives available for investors. The different indexes and their respective tickers are presented in Appendix 1.

One could argue that financial markets in the US have not faced a period of significant financial distress since 2011 until COVID-19 crisis of 2020. According to the St. Louis Fed Financial Distress Index (STLFSI3), the average financial distress has stayed mostly negative throughout that period and well-within the limits of previous financial crisis of techno bubble of 2001-2002 and GFC 2008.

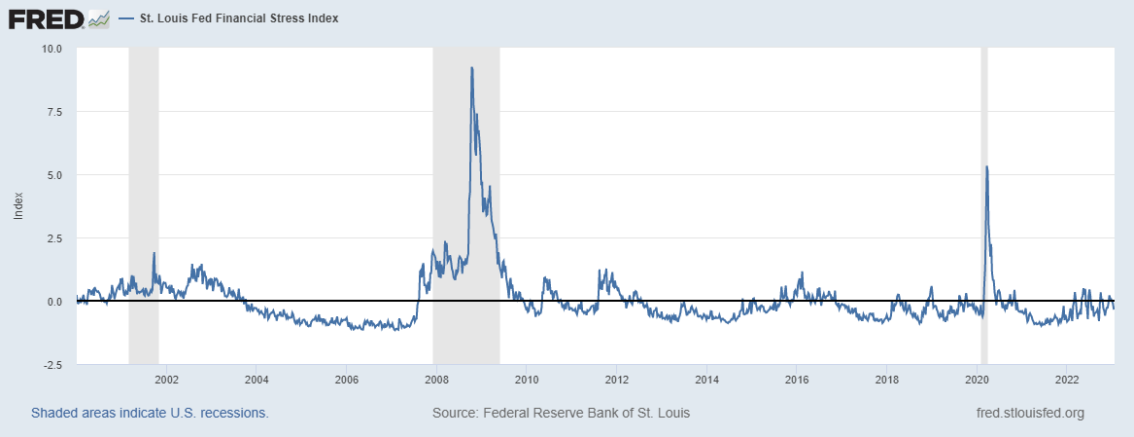


Figure 2 St.Louis Fed Financial Stress Index 1.1.2000-31.1.2023, (Federal Reserve Bank of St. Louis, 2023)

2.2 Portfolio theory and CAPM

Portfolio theory was developed by Harry Markowitz in 1952. Theory was one of the first to take on investment strategies from the investors point of view, instead of classical consumer – manufacturer point of view from microeconomics. As such the theory can be extended to different asset classes. Portfolio theory laid foundational theory that an investor can obtain diversification benefits and thus by increasing the risk-adjusted

return of a portfolio by diversifying investments. Portfolio theory expects returns of assets to be normally distributed in short periods.

The risk in any market can be split between the systematic risk (market risk), which is equal for all assets in the selected market or asset class, and unsystematic risk (portfolio risk), which is effectively the risk carried by individual assets. An investor always carries the market risk as it is shared by all of the assets in the market. Unsystematic risk can be affected by portfolio selection as described by Markowitz (1952). Diversification benefits can be reaped if portfolio can be constructed in such a manner that either the risk is similar, but returns are higher or by having equal returns but lower risk.

For investor to achieve diversification benefits, thus increasing the risk-adjusted return of a portfolio, the correlation coefficient between assets in portfolio need to be considered to be something else than perfectly correlated. If the coefficient of assets in two asset portfolio is -1, there are no diversification benefits as there are no profit from investments as one asset's price movement cancels the other. Similarly, if the coefficient is 1, the assets can be considered to be similar and thus there are no diversification benefits as the price movement of both assets are equal. Thus, the assets need to have correlation between the -1 and 1. Importantly, theory shows that by investing into uncorrelated financial assets in an international portfolio, the risk of one asset can be used to offset or limit the risk of another asset.

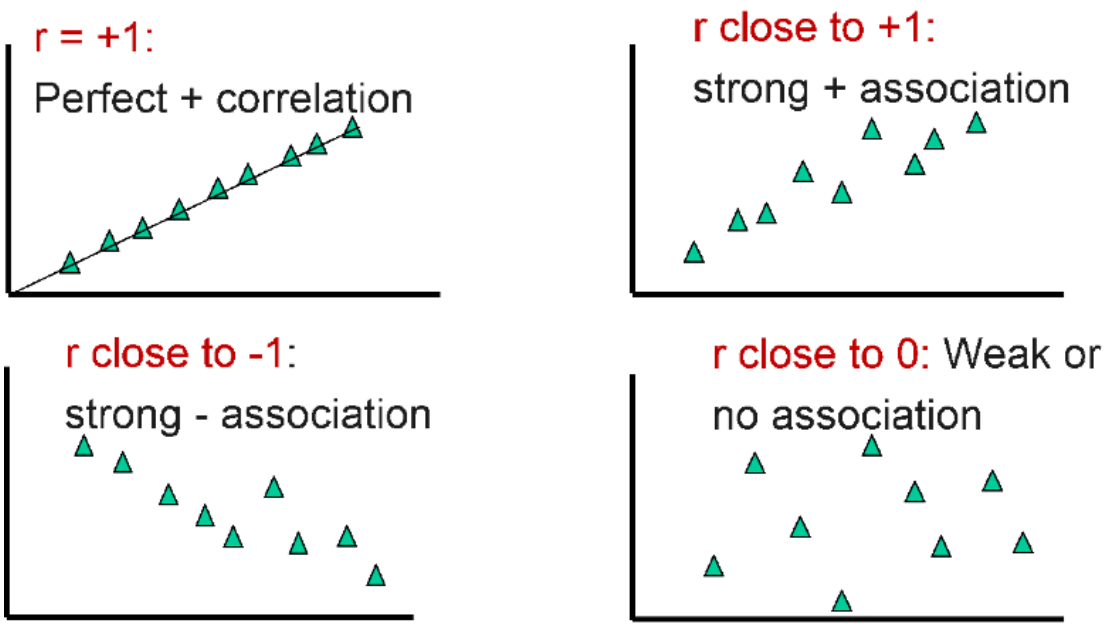


Figure 3 Correlation coefficient visualisation

An efficient frontier can be selected from a number of assets in a market. Efficient frontier reflects all the possible portfolios of market. Minimum variance portfolio is a portfolio of such which is a combination of risky assets that minimizes standard deviation (risk) of the portfolio. An optimal market portfolio consists of at least one risk-free asset and converges with the tangent of capital allocation line. Capital allocation line describes the reward to risk -ratio of different assets with expected returns and standard deviation unit of asset. Individual asset's location in capital allocation line can be lowered by combining a risk-free asset in portfolio or by leveraging investment position of an asset.

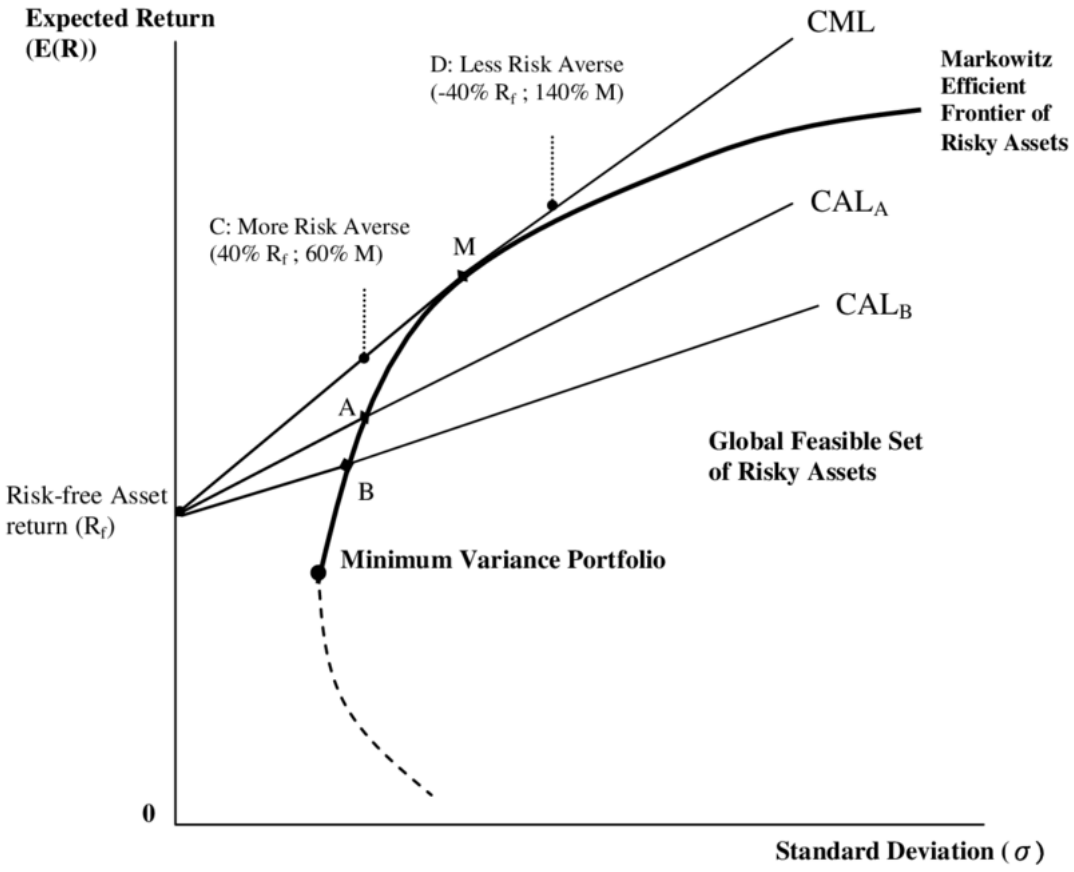


Figure 4 Efficient frontier

Portfolio theory was expanded with Capital Asset Pricing -model (CAPM). CAPM explains that with assumptions on joint distribution of asset returns from t-1 to t and constant risk-free lending and borrowing rate that asset valuation can be achieved in relation to the beta of the asset and general market returns. The model produced introduces market-based risk premium. According to the model, the return of an investment is linked purely to the risk level of an asset in relation to market risk and 'risk free' returns . Stocks which are riskier (less risky) than market have been described to be 'aggressive' ('defensive').

APT was introduced by Ross (1976) as an alternative to CAPM. Unlike CAPM, APT (Arbitrage Pricing Theory) does not assume markets to be efficient all the time. There are assumed to be mispricing of securities, but such mispricing events are temporary as

markets always correct deviations of security prices when such arbitrages are found. APT tries to explain the rate of return of an asset based on similar risk premium as CAPM. The difference between these models culminates in the beta of an asset. While the CAPM concentrates all the variables in one beta of an asset, APT slices this to multiple explaining factors. APT factors are systematic risk factors, and thus these factors can only explain macroeconomic risk, not company specific risks.

Most famous expansion of the CAPM was introduced by Fama and French (1992) in which it was discovered that the market beta cannot predict the returns alone and as such some other variables are required for the model to work accurately. Additional factors introduced by Fama and French (1992) were size and value. Since then, new research has been published which have introduced a great number of different beta variables for investors to consider. Each of these variables however have same risk aspects as the primal CAPM variables.

More recently a number of papers have highlighted the importance of including either systematic risk or tail risk in portfolio optimization (see, Harvey et al., 2010; Brandt and Santa-Clara, 2006; Cruz-Reyes et al., 2014). The importance of tail risk is highlighted especially in cryptocurrency markets where markets suffer from high volatility.

2.3 Risk management

Risk management is a tool for investors to adjust their portfolio's upside potential and downside threats to balanced levels. While yield and risk are strongly correlated in investment universe a wise risk management politic can enhance portfolio's risk adjusted returns and limit investment portfolio's possible downside movement significantly. Traditionally a risk can be expressed in two components: possibility of uncertainty and exposure to this uncertainty.

This thesis focuses on financial risk factors. Value at Risk -measure (VaR) was constructed in order for investors to express a risk level an investment faces at every single point of

time. The measure displays the possible amount of loss and the probability for this loss to realize. Thus, risk manager can set a tolerable level of financial risk, it wants to be exposed to. The benefits of hedging and diversification are displayed when an inclusion of a certain position of a hedging instrument can decrease the VaR -measure for the investor. Measure for financial risk is Conditional Value at Risk (CVaR). CVaR captures only the most unlikely risks (also known as tail risk) of an investment. CVaR was created to supplement the existing VaR -measure by displaying the potential loss in worst case situations. CVaR can be a better measure for investments which do suffer from high volatility, such as the Bitcoin. These measures are potential tools which can determinate weather the Bitcoin can act as an hedging instrument for other asset classes.

Hedging is most commonly executed with future contracts of some asset with an objective of taking a position, which eliminates the risk as far as possible. The case where all risk is eliminated is called “perfect hedge”, which is essentially non-profitable or results in losses (Hull, 2003).

A short hedge is a hedge, where a short position is taken with futures contracts. A short hedge is taken in case where the hedger already owns an asset or is expected to own in some time in future and is expected to sell it in some point in future. A long hedge on the other hand is an opposite position of a short hedge. In this case, the hedger takes a long position with future contracts. It is known that a hedger will have to purchase the asset in future and wants to lock in a price today (Hull, 2003).

Hedging strategies can be roughly separated into two: predictive- and selective hedges. “Selective hedging” was first introduced by Stulz (1996). Selective hedging refers to a hedging strategy, where hedger’s own market expectations determinate when, how many and what positions hedger takes (Yun, 2006). Selective hedging thus includes a speculative attribute in hedging and is greatly correlated with trader’s own skills to understand markets. Adam & Fernando (2006) also point out that gains from selective hedging are small at best. Predictive hedging on the other hand is based solely on

fundamentals of an asset and disregards market price movements (Adam & Fernando, 2006). In case of the Bitcoin, the valuation and thus the fundamental value, in the lack of solid valuation model is absent, the possible benefits might only originate from the selective hedging.

2.4 Flight to quality

Flight to quality events is triggered by unanticipated and unexpected events. Such events are typically described as "Black swan" events, expressions coined by Taleb (2009). These are outliers and can be statistically modeled with tail risks. While these events might be very rare and even unpredictable, tail risk analysis provide investors with important understanding on how exposed they are in market during such extreme market distress. Tail risk hedge (or tail hedge) can protect investors in case of such risks realize and provide important access to liquidity when it is not preferable for investor to sell assets and lending can be extremely expensive.

Flight to quality can be explained as macro event of capital allocation from a riskier asset into a safer one. Such events are observed during high market uncertainty and turmoil. Previously flight-to-quality events have been observed during such events as 9/11 terrorist attacks, Iraq war declaration, global financial crisis or with COVID-19 pandemic. During the different crises of the past a flight-to-quality events, investors have moved their investing position from stocks to assets such as bonds, currencies and different commodities which correlate negatively with stock markets.

A safe haven asset is described by Baur and Lucey (2010) as the following: "*A safe haven is defined as an asset that is uncorrelated or negatively correlated with another asset or portfolio in times of market stress or turmoil.*" Statistically speaking, safe haven asset should either retain or increase the value of portfolio during the financial turmoil. As such, an asset should have zero correlation or correlate negatively with the portfolio pair. An uncorrelated asset is defined as *weak* safe haven asset and negatively correlating asset is defined as *strong* safe haven asset. This distinction is important for investors as

strong safe haven asset should provide investors with positive returns if the portfolio pair decreases in value. This is not the case for uncorrelated asset which only reduces the potential losses. Strong safe haven assets thus should be able to stabilize financial markets by reducing overall losses.

Especially gold has been an interest of many investors and academic studies. Baur and Lucey (2009) find that flight-to-safety movements of capital are not country specific events but global ones. In addition, flight-to-quality event has provided investors with diversification benefit when it has been most effective. In the follow-up study regarding these events Baur and Lucey (2010) study the stock- , bond- , and gold returns of developed markets of US, UK and Germany during the period of November 30, 1995 to November 2005. The study concludes that gold is an effective hedge against stock markets during extreme stock market periods but that the safe haven properties of gold are temporary. Hammoudeh et al. (2010) confirms such behavior during the beginning of the Iraq war of 2003 and concludes that investors who are interested in index-based returns require premium from holding safe haven assets such as gold and silver. However, during the post global financial crisis period a number of studies have started to question if gold is still effective hedge as a result of ultra-low interest rates and monetary policy (see, Klein, 2017; Bekiros et al. 2017; Baur and Glover, 2012)

2.5 Commodities

Commodities are now seen as an alternate type of investment asset and are held in portfolios by institutional investors such as pension funds, hedge funds, and insurance companies. Commodity markets are raw materials, such as agricultural products, energy products and metals. The commodity markets have evolved since the inception in 1800s. Commodities are traded in number of platforms and exchanges. Commodities are described as “real assets” and they tend to react to changing economic fundamentals differently from “financial assets” such as bonds or equities. As such, commodities are usually hailed as effective tool for hedging equities. In the beginning of millennium, the

continuous *financialization* of commodity markets have increased the access for these products for many and from a pricing viewpoint, the presence of financial investors means that, along with fundamental factors, financial motivations are a significant driving force for different commodity prices.

The investment thesis behind commodities as hedge for investment portfolio can be drilled to three points as presented by Nguyen et al. (2020):

1. Low correlation between commodities and other asset classes, especially with equities, on longer period of time.
2. Relatively large returns
3. Positive correlation with inflation

As such, commodity markets have been increasingly financialized with number of instruments such as future contracts and ETFs (Exchange Traded Fund). Institutional investors have used such instruments as part of their investment strategies and portfolios for years now. With increasing market trend for passive ETFs, commodity markets have also become accessible for most of the investors in the world.

2.5.1 Gold

Gold has been considered as an effective inflation hedge as well as important flight-to-safety -destination during the times of financial turmoil for a long time. Economics of gold markets can be separated to demand and supply sides.

Gold as a metal has many purposes across different industries, such activities can be described as “use demand”. Use demand is cyclical by nature as it is affected by economic state and purchasing power of consuming parties. The largest use demand sector is by far the jewellery industry. Additionally, different funds, investors and central banks around the world invest in physical gold reserves, such demand can be described as “asset demand”. Asset demand can be counter-cyclical as gold’s demand can increase in times of recessions and financial turmoil (Baur and McDermott, 2010). Number of

countries have based their currency in the past in gold as well and many central banks have use gold as a diversifier in their respected portfolios. During the first two quarters of 2020, the demand for gold increased rapidly from ETF investments while use demand for jewellery and industrial usage plummeted due to weak economic state and consumer demand.

The supply of gold is relatively fixed, while increasing slowly, as the two main supply channels are recycling and mining operations. While gold is found around the globe, the grade and intensity of gold sources different highly. Bernstein (2000) describes that in order to mine 500 tons of gold, which was the annual output of South Africa in 1996, one has to move over seventy million tons of earth to be raised and milled.

It has been also argued that gold is in unique position regarding the asset price formation. Gold is traded around the world, 24h in a day, and due to the history of gold it has also non-financial components as well. Especially during financial and political turmoil, gold markets can deviate from efficient market hypotheses, due to the role gold plays as a store of value. (Aggarwal & Lucey, 2007) Unique role of gold has been positioned throughout history as part of different cultures, religions, rituals, and political prestige.

The first gold ETF was created in 2003 by gold bullion securities ETF, backed by the World Gold Council. This was a major change in gold markets as ETF offered a new source of demand for gold in addition to the fact that investors could purchase and trade gold more easily than ever before. Ivanov (2013) finds that the position of future contracts in gold markets has diminished since and that gold ETFs have taken the role of price discoveries in gold markets. As such, gold ETFs are found to be extremely accurate in tracking the gold price index, with spread of only 20 basis points as observed by Ivanov (2013).

Most interestingly Sumner et al. (2010) find no spillover effects between gold and stocks in the US between 1970 and 2009. Lack of such relationship indicates that gold can lower the risk profile of an investment portfolio. Lucey and Li (2015) however highlight the

importance of time component in this equation as the save haven properties of gold is found to be inconsistent. While in some quarter's gold is found to be safe haven and not in some others.

2.5.2 Oil

Oil has been described as "black gold". It serves as a fuel for the world's economy due to it's role as an energy source for different industries. The most frequently used benchmarks for crude oil prices are the WTI Cushing Crude Oil Spot Price, traded at the New York Mercantile Exchange (NYMEX) and the North Sea Brent, traded at the Intercontinental Exchange (ICE).

The co-movements between crude oil and stock market prices can be explained by asset pricing theory. An increase in oil prices would result in higher production costs for companies that use oil, reducing expected cash-flows and causing a decrease in stock prices. On the other hand, for oil-exporting nations, higher oil prices bring about increased revenue, leading to an increase in stock prices. Additionally, the rise in oil prices also contributes to the overall growth of the economy in these countries, as the oil-exporting industry experiences increased income. This growth in the economy can be reflected positively in the stock market (Junttila et al., 2018).

The spot price of oil is fundamentally based on the market's supply and demand. Behmiri and Manso (2013) describes carefully that crude oil prices reflect multiple factors such as political, financial, technological, meteorological, and economical. In the United States, the role of oil in economy has been resilient despite push for green energy. As presented in Appendix 1, the U. S. Energy Information Administration (USEIA) reports that in since 2000, the share of crude oil as energy source for consumption has been steady despite increased use of solar- and wind energy. As presented in Figure 5, the sectoral distribution for petroleum products presents the dominative role of oil products in the US economy. In addition to these factors, oil is also considered a non-renewable

resource and as such scarcity and speculations are to be also considered as relevant pricing factors according to Hamilton (2008).

In addition, US has the largest known emergency supply of oil – the Strategic Petoleum Reserves (SPR) which is maintained by United States Department of Energy. SPR has been used to steady the price formation of oil as reserves have been replenished when the price of the oil has been low and on the other hand reserves have sold products to markets when the price of oil has been high. This mechanism has increasingly been used during the COVID-19 pandemic to stabilize the oil markets.

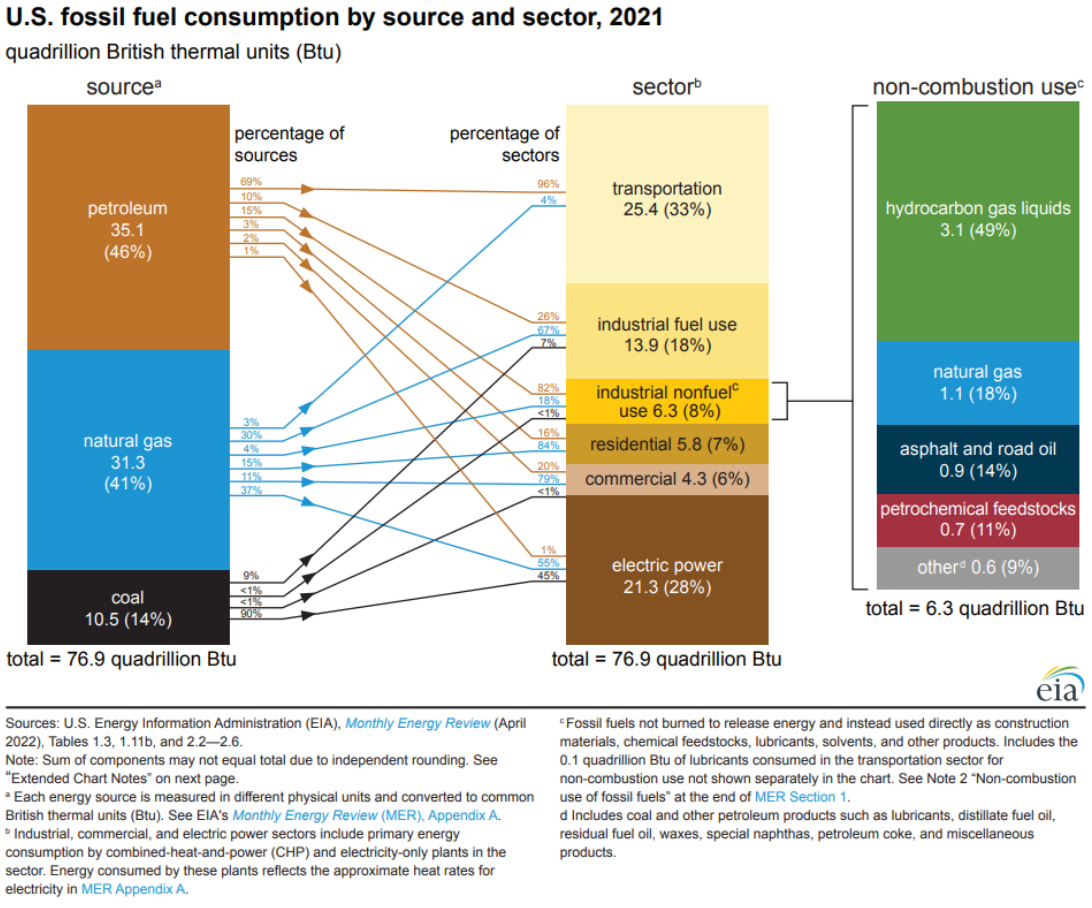


Figure 5 Fossil fuel consumption by source (USEIA, April 2022)

For years of 2020 and 2021, United States was once again net exporter first time since the year 1949. Petroleum imports peaked in 2005 and since then, domestic production and refinement has gradually increased every year (USEIA, 2022).

2.6 The Bitcoin

Theoretical framework for cryptocurrencies was introduced by Haber and Stornetta in 1990. The paper did propose a technical standard on how to create a chain of unique digital fingerprints to the documents itself, not to the medium of exchange, which can't be back-dated or forward-dated. Such technology was crucial part of any decentralized transactional service.

In 2008, Nakamoto, a person or group of persons published the white paper for the bitcoin. The paper was inspirated by the growth of e-commercy and lack of trust towards a central-party orientated financial system. The bitcoin combined different technologies such as timestamp-server, SHA-256 encryption, decentralized network, and proof-of-work protocol. At the end, bitcoin transactions would be based on cryptology and not on trust between transaction parties.

The core of the bitcoin relies on the encryption technology. This does require computational power from a network of computers. The participated computers are tasked to calculate cryptological problems in order to confirm new blocks in the blockchain as well as verify past blocks. These problems increase exponentially as new blocks are introduced to the blockchain which results in need of more time and more advanced computational power. These problems are solved in most cases by the GPU (Graphics Processing Unit) of a computer. Special GPUs designed for the Bitcoin proof-of-work capacity have also been introduced but the availability of such GPUs is limited.

The bitcoin did not set out to overthrow US Dollar as the dominative currency, but to introduce an alternative for it. The systematic difference in the environment and design of the Bitcoin does provide many benefits for users. The low transaction fees itself does

provide an opportunity for people to send the bitcoin globally relatively free when compared with traditional wired transfers of currency. Additionally, low transaction fees can prove to be attractive for FX traders. Finally, the Bitcoin does to reveal or collect personal information between parties.

The Bitcoin does not have intrinsic value and is considered purely a speculative asset (Cheah and Fry, 2015). As such, an accurate valuation model for the Bitcoin cannot be presented. This differentiates cryptocurrencies from other financial assets, making it attractive especially for speculative traders and technical analysis. As a result, a large portion of current cryptocurrency trading is executed by high frequency trading robots and algorithmics which utilize big data, artificial intelligence, and complex trading rules to profit from markets. Many cryptocurrency exchanges encourage for this type of trading as transaction fees are generally low in cryptocurrency markets and volume can offset this sector for exchanges. Many exchanges do offer free APIs (Application Programming Interface) and entry to trading data to attract new customers. This does also provide easy access to interesting data for academics. However, the Bitcoin does suffer from lower liquidity levels when compared to gold, oil or equity markets.

The popularity for the bitcoin can be explained by number of factors, such as media attention, low transaction costs, anti-establishment status, and solitary from rest of the world. The increased interest in different cryptocurrencies, can be measured with surge in trading volumes, market capitalization and academic attention (Corbet et al. 2019).

Different cryptocurrency exchanges have grown in size and transaction volumes while the Bitcoin has attracted more investors. As such the trading has shifted mostly for different exchanges and only some individual trades are made outside these platforms. Such development has provided the Bitcoin to have a higher liquidity and constant market price. Exchanges offer their API (Application Programming Interface) for investors and researchers for free in order to attract more transactions. Such APIs are widely

utilized by different trading programs and research platforms. Aggregated trading volumes and trading prices are collected by number of operators such as Yahoo finance.

The Bitcoin futures and options were recently offered by CBOE and CME. Futures were announced during the 2017 and with increased attraction from investors, separate option contracts on futures were presented during January of 2020. In October of 2021, a separate Bitcoin ETF was launched by investment firm VanEck. Option trading of the Bitcoin has also be hailed by more traditional investment banks, such as Goldman Sachs.

The only way to increase the supply of Bitcoin is by so-called mining activities. As such, they can be compared with central bank mints which print new currencies to circulation. These “miners” are computers which try to solve exponentially more difficult calculations for the Bitcoin blockchain. As a reward, they receive newly generated bitcoins. The most important component for these mining computers is the GPU (Graphics Processing Unit) of the computer. Bitcoin mining operations will use thousands of these computers and high-powered GPUs to be the first to solve blockchain’s new calculations and to be the ones to receive the new Bitcoins.

The miner’s cost consists of mainly two parts. The mining cost and liquidation cost. The mining cost (or running cost) is mainly the electricity which is used in running and cooling computers. Due to this it is not economically valid to mine bitcoin if electricity costs rise past certain point. Kristoufek (2020b) finds that bitcoin mining is indeed pushed to areas where the price of electricity is low and calculates that mining operations are profitable in areas with electricity price equal or under 0,04$/kWh. Liquidity cost consists of mainly the price drops of Bitcoin and marginal cost of bitcoin exchange when converting from Bitcoin to fiat currency.

The Bitcoin and cryptocurrencies in general are relative new asset class. As such, academic interest towards these instruments is quite recent and the topic suffers from a low number of academic research when compared to other financial topics. Regardless

of this, with rising interest from public and financial institutes, the number of research covering cryptocurrencies and the Bitcoin is increasing rapidly. The maturity of the markets however has also developed at astonishing speed and as such it is crucial to understand that older academic research is constantly being replaced with more recent studies.

2.7 US bonds

Bonds provide fixed income for investors to receive, with principal amount returned after the investing period. Such instruments are mainly available for institutional investors and thus trading volumes of bond markets is typically high. Bonds are typically issued by governments, government related entities or corporations. Bonds are typically purchased by institutional investors such as funds or banks. US treasury bonds which have maturity of 10 years or longer are considered 'risk-free' assets by investors in general. Bonds are valued by calculating the present value of future cash-flow. Fabozzi (2010) presents the valuation formula for yearly coupon payment bond as following:

$$P_0 = \sum_{t=1}^{n} \frac{C_t}{(1+r)^t} + \frac{FV}{(1+r)^n}$$

where:

P_0 = Bond's price today

C_t = coupon payment

FV = face value or par value

r= yield required by investors

n = number of coupon payments

t = time period when payment is received

The most commonly used measure for bond valuation is Yield to maturity (YTM), which is calculated as the yield that makes the present value of future cash flows equal the current value of current market price of the bond. Noticeable, there is an inverse

relationship between the yield of the bond and the current value of the bond: as yields increase, the current market value the bond decreases as the future coupon payments (cash flow) is fixed. These daily yields are for U.S. Treasury bond with 10-year maturity is presented in the following Figure 6. Grey area highlights times of financial distress, the dot-com bubble of 2001, Global Financial Crisis (GFC) of 2008 and COVID-19 crisis of 2020. These yields tend to lower in such times as investors prefer such secure instrument in times of financial distress as presented by Baur and Lucey (2009).

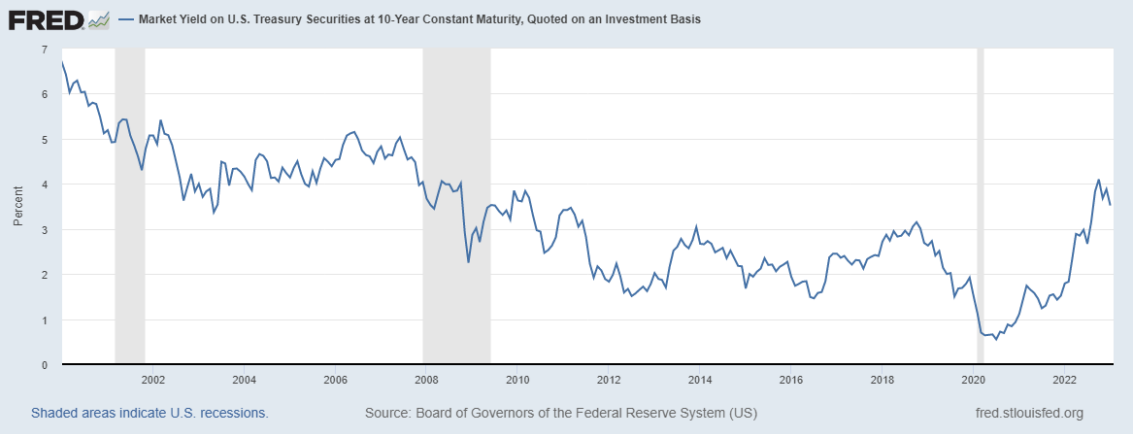


Figure 6 Market Yield on U.S. Treasury Securities at 10-Year Constant Maturity, Quoted on an Investment Basis (Board of Governors of the Federal Reserve System (US), 2023)

A U.S. Treasury bond is a debt security issued by the federal government to raise funds for various government spending initiatives. The 10-year Treasury bond is a type of long-term bond with a maturity of 10 years, meaning that the bond will mature, and the principal will be repaid to the investor in 10 years.

U.S. Treasury bonds are considered to be among the safest investments because they are backed by the full faith and credit of the U.S. government, making them a low-risk option for investors. As a result, they are widely used as a benchmark for other financial instruments and are often used as a gauge of overall market interest rates.

The yield on a 10-year Treasury bond is determined through a competitive auction process in which the U.S. Treasury Department sells the bonds to investors. The yield on

the bond reflects the cost of borrowing money for 10 years and is used as a benchmark for other long-term debt securities, such as corporate bonds.

The U.S. 10-year Treasury bond is used as a benchmark for other financial assets because it is considered to be a low-risk, highly liquid, and widely traded investment that provides a benchmark for the market's expectations of future interest rates and the risk-free rate of return.

2.8 COVID-19

The first COVID-19 case of the world was reported by the WHO on 31st of December 2019 in Wuhan, China. The virus was declared as a pandemic by the WHO on 11th of March 2020. In the early wake of COVID-19 little was known of this virus as drastic measures were taken by countries and local authorities to limit the spread of the virus. The pandemic was described as “once-in-the-century” pathogen by Gates (2020), which underlines the initial reaction to this pandemic. International monetary fund (IMF) has estimated that, the global financial repercussions can be over 12,5 trillion US dollars (Shalal, 2022). While the economical consequences of COVID-19 pandemic are massive, the financial crisis is also a complex structure as it is nothing like previous financial crisis previously.

Market reaction was initially harsh with S&P 500 index declined over 30%. However due to the strong reactions by FED and ECB markets did recover in record-breaking speed with S&P 500 index breaking the previous all-time-high index value in August 2020. Since then, S&P 500 has been rising considerably.

During the pandemic, number of different variants and sub-variants have been detected as a dominant form of the virus. Such behaviour is natural and expected from any viruses, this has also presented a dynamic factor for global economics as well. The hotspot for virus has shifted around the globe during the pandemic as a result of these variants,

disturbing global supply chains and local business operations. In the US, the pandemic was the fiercest in terms of deaths during the beginning of 2021.

There is no exact scientific definition for when a pandemic ends, but it is generally understood to mean a decline in the number of new cases, hospitalizations, and deaths over a sustained period of time, accompanied by a reduction in the spread of the virus in the population.

Ultimately, the end of a pandemic is a complex and multi-faceted phenomenon that depends on a range of factors, including the nature of the virus, the effectiveness of public health interventions, and the ability of communities and populations to maintain vigilant and effective response efforts. It is a dynamic process that may take some time to fully unfold, and it may be subject to changes and fluctuations over time.

While COVID-19 virus might continue to live among the human population, the endemic case of the virus is still too early to be predicted with possibilities of new variants and unpredictable direction of new medical developments in vaccines and treatments. As such, this thesis interprets the end of observation period to end of dominant role of “delta” variant of COVID-19 and the beginning of dominant COVID-19 variant of “omicron” in the USA. According to CDC, this shift was confirmed on December 20, 2021, when 73% of new detected cases were of omicron variant.

3 Literature review

3.1 Gold

Stock markets and gold has been a topic of number of research. After the previous financial crisis of 2008, Baur and Lucey (2010) authored paper to study the effectiveness of gold in terms of hedging abilities and safe haven attributes. By using regression model with stock and bond markets as an explanatory term for gold returns for a long period of time since 1988. The results show that gold is an safe haven asset for developed markets of United States, United Kingdoms and Germany. However, the safe haven attributes can change in time, and they are not present at all of the time. Gold is analysed to be safe haven during extreme turbulence in financial markets, but not outside these periods. As such, gold is a safe haven asset when it is required. Additionally, gold is a stronger hedge against stock market in bear markets than in bull markets in the United States.

Hood and Malik (2013) evaluate the role of gold as an hedge and safe haven against the US stock market when compared with volatility index VIX. Hood and Malik (2013) employ similar methodology as per that of Baur and Lucey (2010) in order to compare these instruments. Using daily data from 1995 to 2010, analysis covers the major financial crisis of dotcom bubble and great financial crisis of 2008. The results indicate that while gold does present itself as an strong hedge, VIX does offer significantly better alternative to gold. Additionally, gold is found to be string safe haven in 10% quantile while VIX presents itself as an strong safe haven in all quantiles (10%, 5% and 1%).

COVID-19 pandemic inspired a number of papers to further research gold's ability to act as a safe-haven and hedge against equity markets in unstable periods. Number of papers find gold as an effective safe haven (Ji et al. 2020; Salisu et al. 2021; Tarchella and Dhaoui 2021), but different results are also observed (Akhtaruzzaman et al. 2021).

In addition to these studies, the effectiveness of safe haven assets has been found to be diminishing (Lucey & Li, 2015). In the extended research by Li and Lucey (2017), they

conclude that political and economic factors can affect the attractiveness of different precious metals as safe haven assets.

3.2 Oil

Jones and Kaul (1996) were one of the first to study to co-decency of oil and stock markets during the post-war period of 1947-1991. By using the cash-flow dividend valuation model the study finds negative relationship between oil and stock returns for US and Canadian markets. However, for UK and Japanese markets, similar explanation is not found in similar setup.

Previous studies have also studied the effects of financial distress on the correlation between oil and stock markets. Filis et al. (2011) deployed DCC-GARCH-GJR model to focus on the time-varying correlation between oil and equity markets in order to identify the possible changes in correlation in times of financial distress. The analysis was conducted individually for oil importer -countries and oil exporter -countries. Interestingly, results indicated that there was no difference between these two sample groups. Similarly, results did indicate that there was a positive correlation between these two assets when there was an aggregated demand-side oil price shock, such as GFC of 2008 but not when the shock was caused by precautionary demand. In such cases the correlation was found to be negative. Similarly, supply-side shocks did not influence asset correlation. Filis et al. (2011) conclude that non-economic crisis triggers a strong negative correlation between oil and stock markets while economic crisis triggers a strong positive correlation between these assets.

Junttila et al. (2018) study the time-varying correlation between US equity markets and WTI crude oil future prices using the Engle's (2002) DCC-GARCH model for time period of 1989 to 2016. The results shows that correlations between crude oil with stock market returns change over time, affecting dynamic hedge ratios and optimal portfolio shares. During stock market selloffs, crude oil and the S&P500 become more positively correlated, indicating poor performance for crude oil to act as hedge against US equities. The

GFC of 2008 was a major turning point in the data, with cross-asset correlations remaining higher even after the crisis. Crude oil futures and energy sector equity prices have become more closely linked already since 2004. Junttila et al. (2018) explain this as a likely effect of financialization of commodity markets. However, this closer linkage makes crude oil a less attractive instrument for hedging against US energy sector equity investments (Junttila et al., 2018).

Batten et al. (2021) study the possibility of hedging stocks with oil. The main reasoning presented for oil to be effective hedge is that cashflow is much stronger in financial crisis for equity stocks when compared with commodity products. During the previous GFC of 2008, the effectiveness of hedge ratios jumped and thus increased the effectiveness of using oil as a stock hedge. However, since 2008 there has been several macroeconomical and political developments such as COP21 and COP23 agreements which are expected to drive demand for oil downwards. Using the data from January 1990 to December 2017 and by deploying DCC approach introduced by Engle (2002), hedge ratio between returns of various stock market indices and Brent oil is illustrated in following Figure 7.

Hedge ratio

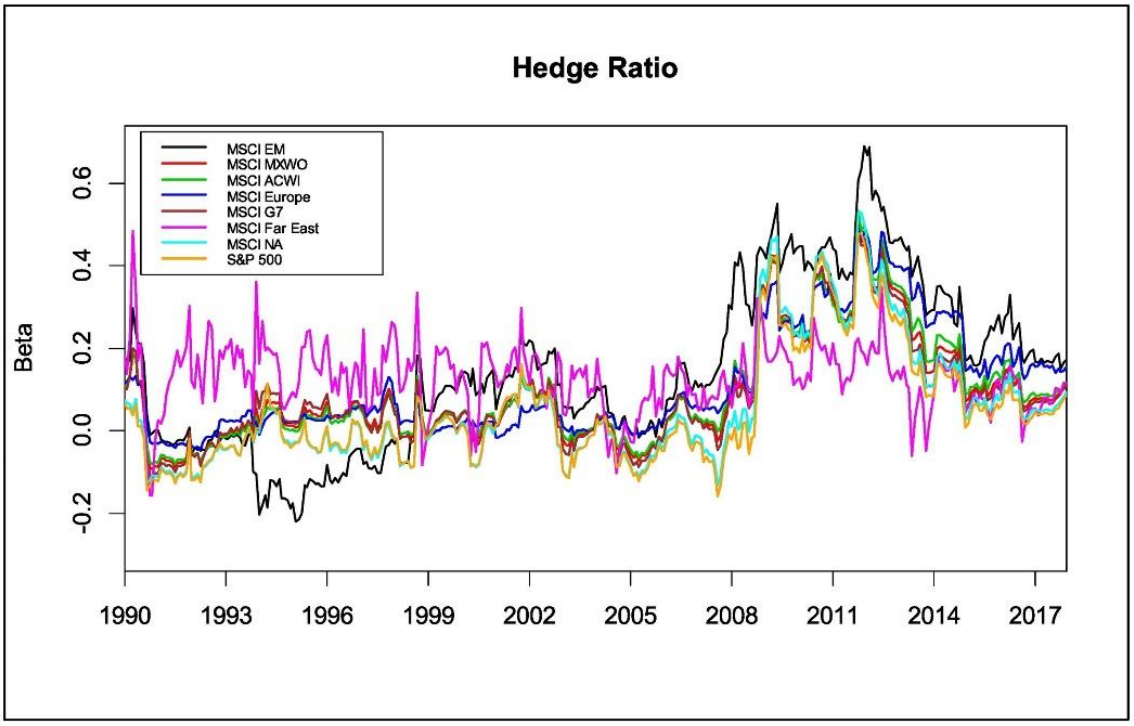


Figure 7 Hedge ratios (Batten et al. 2021)

Most noticeable increase in hedge ratios are timed during the GFC which after average hedge ratios remain positive. Batten et al. (2021) provide explanation for this phenomenon, the onset of quantative easing (QE) programs all over the world which were most notable launched in US by Federal reserve in November 2008 and European central bank in May 2009. QE changed the covariance between stocks and oil from negative to positive. In order to assess the effectiveness of these general hedge ratios, different approach is taken following the study by Dale (1981) which shows the proportion of the variance that is hedged. With perfect hedge achieving value of 1 and no hedge achieving the value of 0, time varying hedge effectiveness is displayed in following illustration (Figure 8). Most noticeable S&P 500's average hedge effectiveness is reduced to just 3,45% whereas other developed markets maintain high time varying hedge effectiveness.

Hedge effectiveness

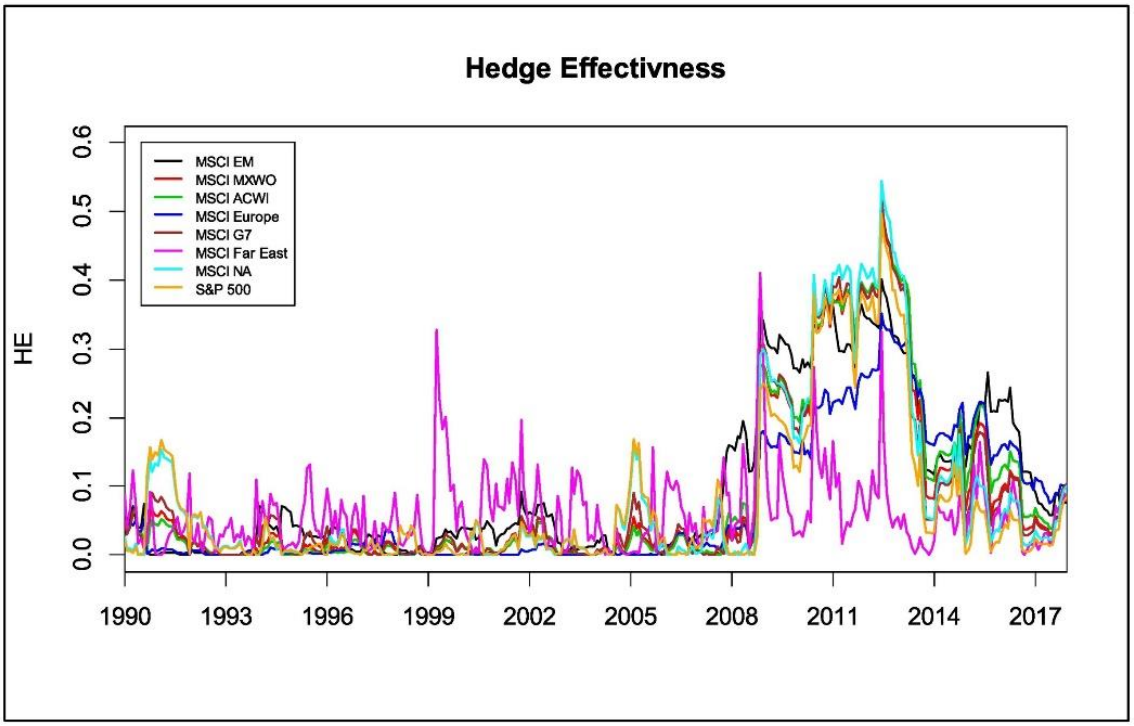


Figure 8 Hedge effectiveness (Batten et al. 2021)

3.3 Bitcoin

For Bitcoin, Dyhrberg (2016a) deploys asymmetric GARCH model, similar which is used with research related to gold, to inspect different capabilities of the Bitcoin. This dataset covers the period from 19th of July 2010 to 22nd of May 2015. This study compares previous academic research on the properties of gold with findings from the Bitcoin analysis. Such similar aspects are the following: no signs of drift, low convergence to the long-run equilibrium, volatility clustering, and high volatility persistence. As a conclusion, Dyhrberg (2016) presents the Bitcoin combines the benefits from, both US dollars and gold, and as such can be used as a useful risk management tool for portfolio management.

Bouri et al. (2017a) uses a DCC-GARCH model to examine whether the Bitcoin acts as a safe haven asset against S&P 500 stock index. Their data covers the period from the July 2011 to December 2015. They conclude that the Bitcoin can act as an effective diversifier for S&P 500 index, but not as a safe haven during extreme market movements. The time

varying difference however was notable. For weekly and daily data results were different for DAX 30, Shanghai A-share, MSCI world and MSCI pacific. As a conclusion, Bouri et al. (2017a) presents that due to the daily price fluctuation the Bitcoin can only work as a daily diversifier but for some markets, especially in Asian stock markets, it can also act as both a strong safe haven and diversifier depending on the time horizon.

Another research from Bouri et al. (2017b) studies the relationship between the global uncertainty (proxied by VIX index) and the Bitcoin returns by using standard OLS methodology and wavelet-based quantile-in-quantile regression. Their data consist of daily sample from 17th March 2017 to 7th October 2016. While in their results the standard OLS regression indicates that the Bitcoin is affected negatively by global uncertainty in financial markets, the quantile-in-quantile indicates that the Bitcoin can be used as an hedge against uncertainty, especially in shorter investment horizons (2-4, 4-8, 8-16, 16-32 or 32-64 days). The study concludes that in shorter investment horizons, Bitcoin can act as a hedge during extreme bear and bull markets but only for shorter investment horizons.

Baur et al. (2018) analyze the statistical properties of the Bitcoin and stock markets between July of 2010 and June of 2015. This analysis presents that the correlation between the Bitcoin and S&P 500 index are not correlated in returns. Additionally, the Bitcoin and gold share some of the properties, such as limited supply, non-centrality and independence from central banks or governments. As a conclusion, Baur et al. (2018) do present the Bitcoin as an safe haven asset and an alternative to gold, but argue that the Bitcoin's ability to act as a safe haven derives from the fact that the Bitcoin does not play (at the time) an important role in global financial markets and thus is comparable independent and unique asset class.

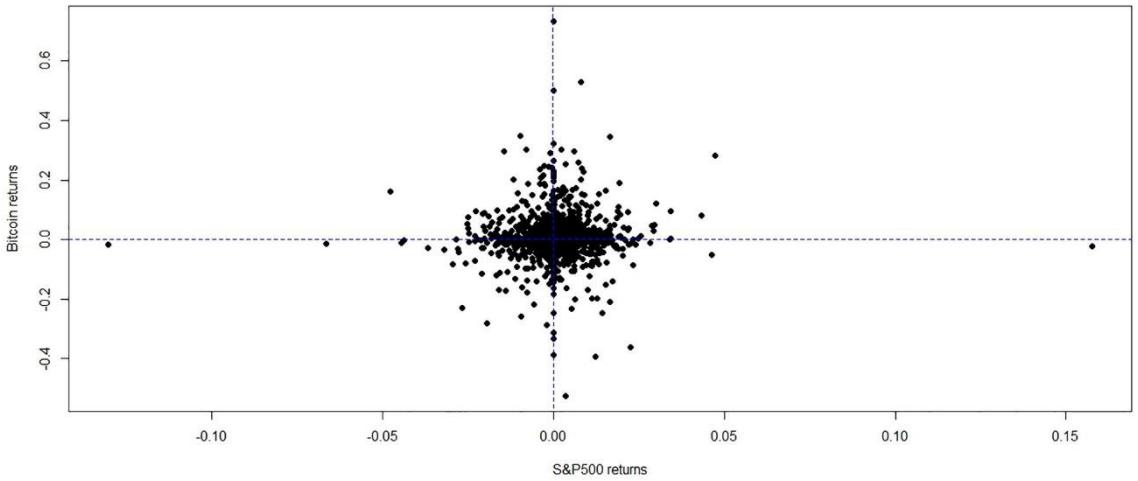


Figure 9 Scatter plot of the Bitcoin and S&P 500 returns (Baur et al., 2018)

Bouri et al. (2020a) study the hedging capabilities against US MSCI stock index in sight of increased trade disputes between the US and China. With China contributing (at the time) a majority share of the Bitcoin trading activity (66% of global bitcoin markets at the end of 2017) due to the relatively cheap electricity availability. The observation period for the study is from October 2011 to May 2019. In their study, Bouri et al. (2020) deploy unconventional two-step method. First, by converting daily returns to and relating this to growth in trade uncertainty by using ordinary least square (OLS) regression. Study finds that the Bitcoin acts as a hedge for US equities during increased policy-related trade tensions between the US and China.

Corbet et al. (2020) released on of the first studies covering the Bitcoin performance as an hedge during the first weeks and months of COVID-19 pandemic. They observe increased trading activity in cryptocurrency markets between the WHO declaration (January 5th 2020) and first case of international transmission of COVID-19 (13th of January 2020). To check the sentiment of markets, Corbet et al. (2020) collected twitter data mentioning COVID-19 related terms and cryptocurrency related terms from January 2019 to March 31st 2020. By employing a standard GARCH (1,1) model, the results indicated that during these periods a significant and time-varying price-volatility developed

as the information about COVID-19 pandemic increased. During these periods of market panic, the cryptocurrencies acted as a safe haven.

On the other hand, more recent studies present that the Bitcoin is not comparable with gold in terms of safe-haven asset. Klein et al. (2018) study the properties of the Bitcoin with asymmetric Power ARCH (APARCH) and Fractionally Integrated APARCH (FIAPARCH) models. These econometric models focus on the leverage effect and long memory of an asset. The observation period for Klein et al. (2018) is from 1st of July 2011 to 31st of December 2017. The study findings imply that the Bitcoin returns response asymmetrically to market shocks, same as most precious metals but that volatility declines slowly after an increase. Additionally, with their correlation model, which consist of challenging portfolios of equity + gold and equity + Bitcoin, Klein et al. (2018) present evidence that the Bitcoin and gold act completely different during market distress. The bitcoin does not show a flight-to-quality properties, but in fact completely opposite with positive correlation during market turmoil. However, Klein et al. (2018) admit that during their observation period, the sample size for market distress is low and thus results are not robust.

Conlon and McGee (2020) studies if there are diversification benefits from holding Bitcoin during the COVID-19 crisis by calculating value-at-risk (VaR) and Conditional VaR (CVaR) measures for portfolios consisting of S&P 500 index and Bitcoin. Their observation period consists from March 21st 2019 to March 20th 2020. They find that by including Bitcoin in portfolio with S&P 500 index, the VaR increased by 13,6% and CVaR by 15,3% at 1% confidence level. Such findings indicate that the Bitcoin failed to act as an hedge during the first year of the pandemic and indeed amplified the downside risk of an investment portfolio.

Kristoufek (2020) studies the quantile correlation of Bitcoin and S&P 500 / VIX index during the COVID-19 pandemic. The study observes a close to zero correlation with S&P 500 index which indicates that Bitcoin is a good diversifier for equity portfolio. This held true

especially during not-turbulent financial market periods. During the most turbulent periods of S&P 500 index, the correlation increased significantly. When inspected in terms of absolute values, this correlation was still rather low and as such results were to be compared with gold. The comparison showed that gold was clearly better hedge and diversifier undermining claims which indicate that Bitcoin can act as a substitute for gold during market turmoil.

Grobys (2021) studies the dynamic correlation between Bitcoin and S&P 500 index. The study focuses on tail risks in US stock markets from 2015 to March 18th 2020. For post-evet period of COVID-19 the period is selected from March 12th 2020 to March 18th 2020. Results indicate that Bitcoin performed as a poor hedge with high correlation with S&P 500 during this period with correlation of 0,6353. Gold on the other hand displayed correlation of −0,0633 with S&P 500 index posing a stark contrast with Bitcoin. These findings indicate that Bitcoin is not a useful hedge against S&P 500 index during the early wake of COVID-19 pandemic.

Lavelle et al. (2022) studied the diversification, hedging and safe haven properties of Bitcoin against US stock markets. Their methodology consisted of DCC-GARCH model with observation period from January 2015 to July 2020. The results show that bitcoin is a good diversifier to S&P 500 index. It does not perform as a hedge or a safe haven in extreme market turmoil.

From the investor's standpoint Baur and Hoang (2021) analyse the co-movements of gold and bitcoin during the long period from 2011-2021 and several sub-periods by using methods of time-varying, frequency-dependent and quantile-dependent correlation estimates. The results show near-zero correlation between these assets in all time periods and as such indicates that for investors, these assets can't be considered as substitutes for each other in investment portfolios. As an explanation for this Baur and Hoang (2021) present that either the investors have not adopted Bitcoin in similar narrative as media and academic literature have talked about bitcoin or the reasons are due to unknown

factors, such as a substitution- or a catching up effect, as these factors can lower the correlation in case the assets were highly correlated with each other.

3.4 Bonds

The correlation between stocks and bonds is largely influenced by uncertainties surrounding growth and inflation, as they affect both the equity risk premium and term premium (Ilmanen, 2003). When uncertainty regarding growth increases, the equity risk premium goes up, causing stocks to decrease in value, while bonds may increase in value due to a drop in the term premium, resulting in a negative correlation between the returns of stocks and bonds. Additionally, a positive correlation can emerge from elevated uncertainty about expected inflation, which impacts the common interest rate factor that affects both stock and bond prices (Li, 2002).

Empirically Baur and Lucey (2009) study flight-to-safety phenomena of stocks and bonds in developed markets. The study applies widely used Engle's (2002) DCC-GARCH model on longer time-period to study different flight-to-safety events from 1994 until 2006. The study reveals that such events occur in many countries at the same time, with an explanation of cross-country contagion presented. The time-varying relation with stock-bond matrix is noticeable with stronger negative correlation during the times of financial turmoil.

Chin and Yang (2012) study employs daily stock and bond future data from US, UK and Germany to examine time-varying stock-bond correlation. Using futures, eliminates nonsynchronous trading problem which has been recorded by Ahn et al. (2002). More importantly, Chin and Yang (2012) focus on conditional extreme condition, rather than conditional median correlation between stock and bond markets, this is most important to study possible benefits of diversification in times when it is most needed. To achieve this, study employs copula method. The main advantage of using the copula method is that it can capture the entire dependence between asset returns, not just linear relationships, while the results remain valid regardless of the distribution of returns. The

study finds evidence that in the US and UK, there is proof of strong positive correlation between stock and bond futures returns during extreme bear markets and to a lesser degree during extreme bull markets (Chin and Yang, 2012).

Lin et al. (2018) conducts similar study as Chin and Yang (2012) but by using wavelet analysis, Lin et al. (2018) eliminates the copula method's shortcoming of failing to capture the time-varying dependencies across different frequencies. The study finds that short- and long-run correlation between stocks and bonds vary across different frequencies over time with long-term return correlation shifting from positive towards for the most part negative during the late 1990s. However, a significant positive coherency is found in the high frequency area, especially in the periods of financial crisis. These findings reaffirm a positive correlation between stocks and bonds during the periods of favourable economic conditions. Lin et al. (2018) conclude that investors might only be able to gain limited diversification benefits from stocks with bonds during times of financial crisis, which on the other hand implies that investors tend to sell both bonds and stocks and buying of other assets, such as gold, during such times.

Papadamou et al. (2021) study the effectiveness of government bonds role working as an flight-to-quality destination for country specific stock market, including the US during the COVID-19 pandemic. With limited sample from 2nd of January 2020 to 9th of Aril 2020, study creates panel data tests and wavelet analysis. Most notable, the study observes noticeable correlation change in bond-stock matrix with panel data framework. With robustness test of wavelet coherence analysis confirming these findings, study concludes that during the COVID-19 pandemic there was a clear flight-to-quality phenome in the wake of COVID-19.

Ma et al. (2021) explores stock market volatility on stock-bond and stock-gold correlation with extensive DCC-MIDAS model. The financialization (Junttila et al. 2008) of gold and commodity markets poses number of questions regarding the correlation and hedging ability of bonds and gold against stock market volatility. Data is collected from US 10 year

treasury bonds and S&P 500 index from January 1985 to December of 2019. Results indicate that bonds and gold are affected differently by increased volatility in stock markets, stock-bond correlation has a significant positive impact in long-term correlation and gold has significant negative impact in long-term correlation between assets. Stock-gold correlation is found to be negative before 2004, but from 2005 to 2013 the correlation was positive with decreased to negative in recent years. This is explained with increased financialization of gold assets. Bonds are found to be more effective hedging tools for investors during the times of market turbulence, indicating the diminishing role of gold's ability to hedge sudden market crisis.

4 Data and methodology

4.1 Data

The data consists of daily S&P 500 composite stock index, U.S. 10-year treasury note, S&P GSCI Gold Spot prices, Brent crude oil barrel spot price and and Bitcoin to USD spot price data, which are collected from Datastream. All of the data is denominated in USD. The S&P 500 is weighted based on the market capitalization.

The full observation period is set to be from 1st of January 2020 till 20th of December 2021. Full period is defined as three years before the first confirmed COVID-19 case in Wuhan, China to CDC's announcement that Omicron variant has begun the dominant COVID-19 variant in the US.

As Bitcoin and gold are traded 24 hours a day, 7 days a week and stocks only on trading days, samples are matched with stock data by removing weekends and public holidays from the Bitcoin and gold data. Log-returns are compounded as

$$LOG\_BTC_t = \log\left(\frac{BTC_t}{BTC_{t-1}}\right)100,$$

$$LOG\_S\&P500_t = \log\left(\frac{S\&P500_t}{S\&P500_{t-1}}\right)100,$$

$$LOG\_Bond_t = \log\left(\frac{Bond_t}{Bond_{t-1}}\right)100,$$

$$LOG\_Gold_t = \log\left(\frac{Gold_t}{Gold_{t-1}}\right)100 \text{ , and}$$

$$LOG\_Oil_t = \log\left(\frac{Oil_t}{Oil_{t-1}}\right)100$$

Descriptive statistics for the periods for each respected period are displayed as follows:

Table 1 Descriptive statistics (%)

	LOG_SP500	LOG_GOLD	LOG_BRENT	LOG_BTC	LOG_US30Y	LOG_US10Y	LOG_US5Y
Mean	0,070	0,033	0,016	0,378	0,028	0,015	0,009
Median	0,167	0,080	0,183	0,324	0,000	0,000	0,000
Maximum	8,968	5,601	21,511	19,168	8,201	2,088	1,073
Minimum	-12,765	-5,056	-44,157	-49,397	-6,904	-2,475	-0,902
Std. Dev.	1,661	1,175	3,823	5,051	1,251	0,468	0,197
Skewness	-1,038	-0,362	-3,063	-1,910	0,446	-0,173	0,101
Kurtosis	17,610	7,391	44,039	22,181	10,649	8,841	8,274
Obs.	497	497	497	497	497	497	497

Table 2 Descriptive statistics (value)

	SP500	GOLD	BRENT	BTC	US30Y	US10Y	US5Y
Mean	3728,429	1042,546	56,750	28988,890	219,067	169,600	160,123
Median	3709,410	1043,960	57,270	23835,100	215,746	169,252	160,724
Maximum	4712,020	1204,820	86,460	67559,000	260,205	179,202	163,259
Minimum	2237,400	862,020	16,500	4841,670	187,993	155,546	151,187
Std. Dev.	600,530	62,360	16,593	19688,200	17,712	5,800	2,664
Skewness	-0,128	-0,451	-0,175	0,317	0,158	-0,244	-1,656
Kurtosis	1,997	3,231	1,982	1,524	1,892	2,098	5,504
Obs.	497	497	497	497	497	497	497

Data consist of total of 497 daily observations and is presented in log-change format. Changes are calculated according to the above-mentioned equations. From Table 1 we can see that the median log-change is lowest with US bonds and highest with the Bitcoin. Supported by the standard deviation of 1,251, 0,468 and 0,197, US treasury bonds does seem to have the most stable price formation when compared to other assets. While the negative skewness of return distribution indicates that all of the assets with an exception of US 30 year bond and 5 year bond did have more negative than positive observations, the overall value of assets were higher by the end of the observation period than in the beginning.

Finally, the difference between maximum and minimum daily changes shows that the Bitcoin (73,237) did have the most changes. Decrease of -49% in bitcoin value happened in 12.3.2020 as the market suffered a coronavirus driven selloff. The contagion was high as other crypto and assumed safe-haven assets dropped as well during that day. Selloff was a temporary as the bitcoin recovered fully by 29th of April 2020. Such a selloff however does indicate however that the safe-haven aspect of bitcoin was inflated before the COVID-19 crisis. A major contributing factor for the selloff was attributed to the high levels of leverage employed by investors as some bitcoin exchanges provided leverage levels of as high as 100:1 for customers to use. Additional problem for price discovery can be contributed to wide distributed denial-of-service (DDoS) attack on large crypto exchange of BitMEX platform on 13th of March 2020 (Bitmex, 2020). As such this study uses data from bitstamp exchange.

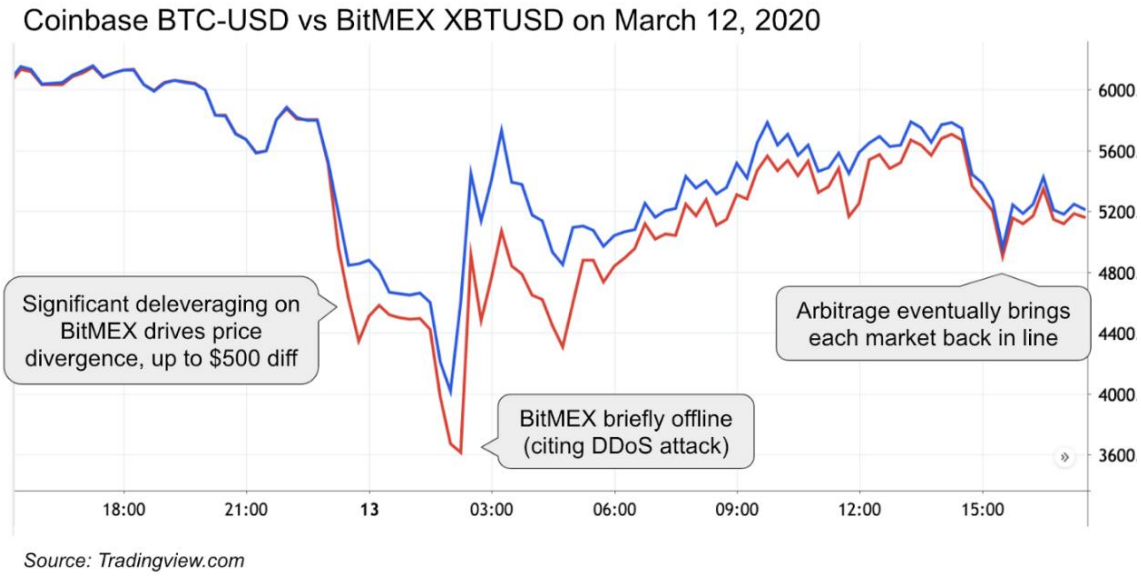


Figure 10 Crypto crash - March 12, 2020

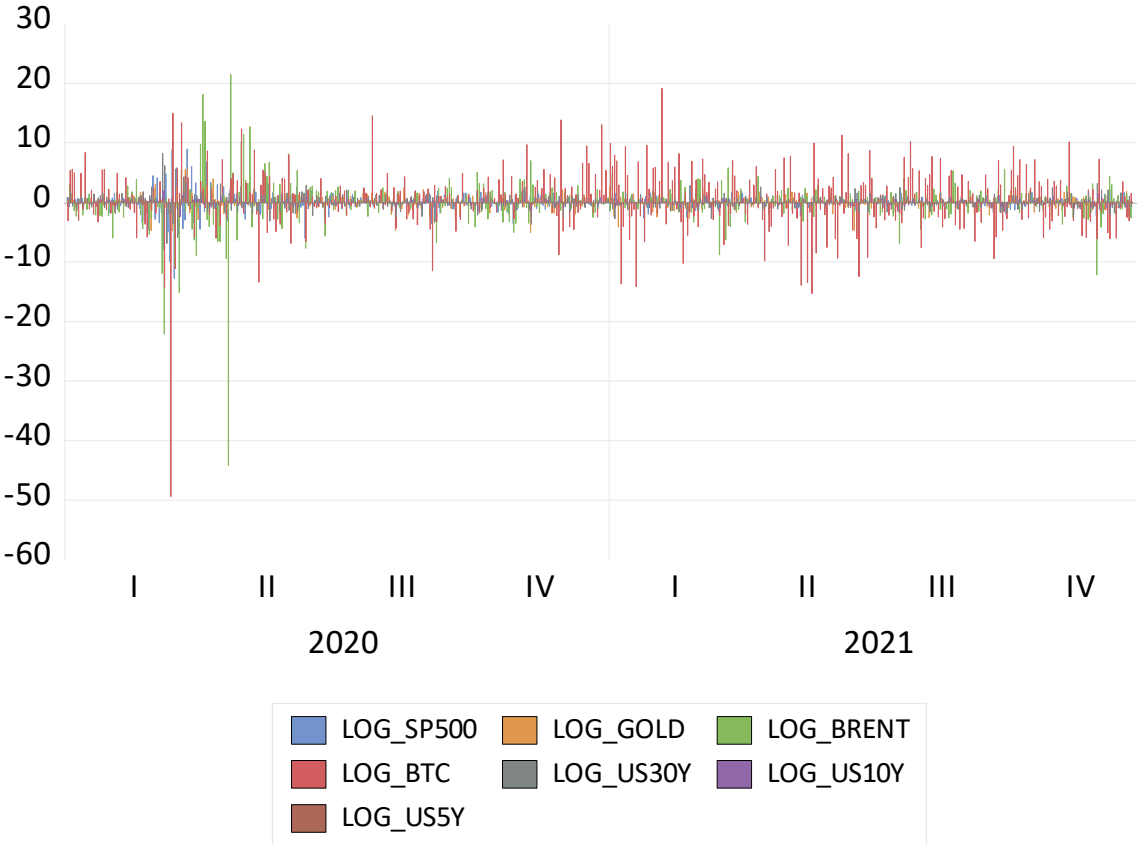


Figure 11 Market volatility time series chart

Figure 11 presents log changes of each asset on unified time scale. As previously mentioned, COVID-19 crisis was a public health crisis which developed into financial one due

to extensive governmental closedowns around the globe and stalled real economic growth. As oil is fuel used in nearly every industry around the world, the price formation of brent did struggle largely as well. The most historic development happened on April of 2020 as WTI crude oil futures were trading at negative -37,63 USD. The demand for oil was disturbed the most as companies halted production and people were under lock-down in their homes. As such, demand plummeted but the supply was constant and as a result, prices declined into point of negative future spot prices in 2020. This study uses Brent oil as a proxy product for global oil markets following the study by Batten et al. (2021).

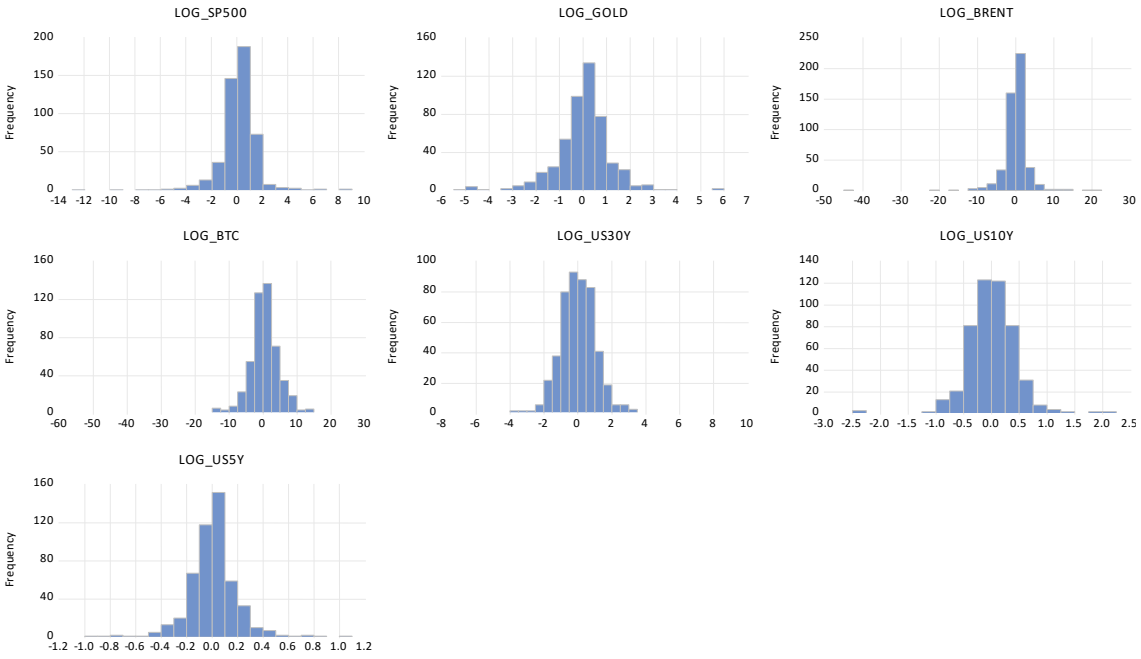


Figure 12 Return distribution histogram

Table 3 Number of observations within the bottom percentile of returns

S&P500		
Percentile	Threshold	Observations
10%	-1,31%	50
5%	-2,32%	25
1%	-5,02%	5

The number of observations of any percentile of returns is notable low in bottom percentiles.

4.2 Methodology

This study follows the methodology established by Baur and McDermott (2010) in their initial research of assessing gold's ability to hedge equity markets during the 2008 financial crisis.

$$r_{asset,t} = a + b_t r_{stock} + e_t \quad (1)$$

where r_{asset} is the returns of an hedging asset (gold, bitcoin or oil). $r_{stock,t(q)}$ account for asymmetries of positive and negative (extreme) shocks and are included in order to focus on falling stock market. This thesis analyses the role of gold, bitcoin and oil in times of COVID-19 pandemic's extreme stock market situations and include regressors that contain stock returns that are in the q% lower quantile during the timeframe, such as the 10%, 5% and 1% quantile. The different thresholds are estimated simultaneously, and as such the parameter b_t can be viewed as following:

$$b_t = c_0 + c_1 D\left(r_{stockQ10}\right) + c_2 D\left(r_{stockQ5}\right) + c_3 D(r_{stockQ1}) \quad (2)$$

In equation 2, $D\left(r_{stockQx}\right)$ is a dummy variable which acquires a value 1 based on weather a threshold has been crossed in stock market's quantile returns. If not, the dummy variable is set 0. This captures any sudden decline in the S&P 500 index. If one of the parameters (c_1, c_2 or c_3) is found to be negative with statistically significant difference from zero, a non-linear relationship between an asset and S&P 500 is found. If all of the parameters are found to be negative, the asset acts as a *weak* safe haven for the stock market. If all of the parameters are negative and significantly different from zero, an asset acts as a *strong* safe haven asset. If the parameter c_0 is zero (or negative)

and the sum of parameters c_1, c_2 and c_3 does not exceed the value of c_0 then an asset acts as a weak (strong) safe haven.

$$h_t = \pi + \alpha e_{t-1}^2 + \beta h_{t-1} \quad (3)$$

Equation 3 presents GARCH (1,1) model to account for heteroscedasticity in the data. All equations are jointly estimated with Maximum likelihood.

The null hypothesis is that the S&P500 returns don't have a significant impact on gold, bitcoin or oil returns. The alternative hypothesis is that S&P500 does have a significant impact on gold or bitcoin returns.

$\mathrm{H}_0: b_t = 0$
$\mathrm{H}_1: b_t \neq 0$

This is consistent with the safe haven hypothesis. If stocks exhibit extreme negative returns, investors buy alternative asset and bid up the price of the asset. If the price of the asset is not affected, investors either purchase nor sell the asset in such adverse market conditions. A negative correlation of gold or bitcoin and stocks in extreme market conditions implies that the price of gold, bitcoin or oil increases in such conditions thereby compensating investors for losses incurred with stock investments.

Tests are conducted for the same time period of 1.1.2020 to 20.12.2021 for each of the assets (gold, brent oil, bitcoin and US bonds). First, the S&P500 quantiles are detected, and dummy variables created for the dataset. Secondly, an OLS regression is run separately which combines equations 1 and 2 into singular function for each of the assets. Thirdly, volatilities are calculated based on the GARCH (1,1) model of equation 3 for the entire data and for the S&P500 bottom quantiles of 10%, 5% and 1%.

5 Results

Results from the model estimated above are presented in Table 3. Statistical coefficients are presented for hedging ability and safe haven quantiles. Below each value is presented the standard error. Statistical significance is remarked with *** for 1%, ** for 5% and * for 10%. The table contains the estimates for c_0 and the total effects for extreme market conditions as presented by the sum of c_0 and c_1 for 10% percentile, c_0, c_1 and c_2 for 5% percentile and c_0, c_1, c_2 and c_3 for 1%

Table 4 Hedge and safe haven assessment

	Hedge	Safe haven quantiles		
		10 %	5 %	1 %
Gold	0,064*	-0,049	0,054	-0,073
	(0,040)	(0,165)	(0,175)	(0,095)
Brent	0,675***	0,701***	-0,341	0,418
	(0,118)	(0,184)	(0,179)	(0,212)
Bitcoin	0,878***	-0,017	0,286	1,450***
	(0,230)	(0,478)	(0,465)	(0,308)
US 30Y	-0,333***	-0,139	0,288	-0,128
	(0,046)	(0,103)	(0,108)	(0,132)
US 10Y	-0,096***	-0,020	0,078	-0,045
	(0,018)	(0,035)	(0,034)	(0,032)
US 5Y	-0,025***	0,003	0,022	-0,034
	(0,008)	(0,015)	(0,015)	(0,013)

For the hedge column, we find that all of the commodity assets and bitcoin correlated positively with the S&P 500 index, while US bonds with 30 year, 10 year and 5 year maturities correlated negatively. With each of the results presenting statistically significant results and positive coefficient values for all expect of US treasury bonds. Thus, only these treasury bonds can be regarded as a hedge for stock markets. Gold, brent oil and bitcoin, however, can be considered effective diversifiers for the stock portfolio as each of these assets correlated with coefficient of less than one and above zero. Each of the diversified asset's co-moves with the S&P 500 stock market index while bonds move on opposite direction. Gold has the lowest positive co-efficient which makes it the best diversifier when compared with brent oil and bitcoin. Gold is found to be significantly

different diversifier with extremely low coefficient. Brent oil and bitcoin do not protect investment portfolios close to the same levels as gold does with difference in coefficients being close to 10 times (0,064 vs 0,675) to oil and over 12 times (0,064 vs 0,878). The low standard deviation indicates that the value change in gold bullions does not deviate largely from the statistical mean. On the other hand, bitcoin is found to be the worst diversifier as it co-moves closely with S&P 500 with coefficient of 0,878. Additionally, the standard error is the highest which does not encourage its role as an portfolio diversifier. Oil is similarly found to co-move with S&P 500 with coefficient of 0,675 but with lower standard deviation term of 0,118 when compared with that of bitcoin's (0,230). For US treasury bonds, longer maturity provides better hedge than bonds with shorter maturity. This can be explained with standard yield curve of U.S government bonds at that time.

Table 4 also shows which assets are weak or strong safe haven assets and which assets does not provide safe haven attributes. Results show that gold is not statistically significant with none of the safe haven quantiles. Such results indicate that gold can't be regarded as a safe-haven asset during the COVID-19 markets. Results in this regard are surprising as previous research about the topic is extensive and well recorded. Co-movement with gold and stock markets would indicate that previously observed change in gold's relationship with stock market could be considered valid. Faced with heavy losses, investors did not shift capital from stocks to gold but instead to other asset classes. One explanation for such behaviour could be found from liquidity of markets and possible leverage rations of both asset classes. Such results, however, could be unique with the COVID-19 pandemic as underlying reasons for the crisis were significantly different from previous financial crises as well.

Oil is not found to be statistically significant in any of the bottom 10% quantile of worst stock market days with coefficient of 0,701. Such high value however does indicate positive correlation and therefore only limiting the losses, not countering them. While there could be diversification benefits during such trading days, there can be no safe haven properties for losses. Therefore, oil can't be considered a safe haven asset as the high

coefficient does indicate that performance of oil is relatively poor for investors when combined with high standard volatility (risk) of such asset.

Bitcoin is found to be statistically significant in bottom 1% quantile of worst stock market days with coefficient of 1,3919. Such high coefficient would indicate high economical significance for this asset. As the coefficient is found to be higher than 1, the results do indicate that the Bitcoin would amplify losses in portfolio as it would not reduce the total losses in bottom 1% of stock returns but in fact suffered higher losses overall during such trading days. However, due to the small sample size definitive conclusions can't be made. Both of the relevant results have positive coefficient which indicates again co-movement with stock markets.

Bonds are not found to be acting as safe haven assets for any of the bottom quantiles. Such finding is relatively surprising considering the widely accepted role of government bonds in previous risk management literature.

For gold these results differentiate from previously mentioned literature which study gold's role in past financial crisis (Ji et al. 2020; Salisu et al. 2021; Tarchella and Dhaoui 2021). These findings are in line with previous gold's role in COVID-19 -literature studied by Akhtaruzzaman et al. (2021). With oil results are in line with Batten et al. (2021) with high coefficient (over 0,5) between stock and brent oil. As indicated by results obtained by Batten et al. (2021), oil does not provide meaningful hedging abilities against stock markets. In case of bitcoin, these findings are in line with Grobys (2021) with findings that bitcoin does not act as an effective safe haven asset or hedge against stock markets during the COVID-19 pandemic. Contradicting previous research by Papadamou et al. (2021), this study does not establish effective safe-haven relationship between stocks and bond markets as none of the US government bonds acted as safe haven assets during the observation period. This however, can be affected by the different sample size as well as different methodology established by these studies.

6 Conclusions

This thesis set out to replicate study from Baur and McDermott (2010) with fresh data from COVID-19 financial crisis. While the initial shock was short, and assets rebounded widely after the decisive actions by central banks, this event provided one of he best scenarios in recent years to test hedging and safe haven abilities of number of assets, including cryptocurrency Bitcoin. In order to test such asset abilities a number of two-asset portfolios were created with stock index S&P 500. Bottom quantiles were selected based on log returns of S&P 500 with 10%, 5% and 1% return values.

In conclusion of existing literature, there are several key points to be raised. Firstly, safe haven assets might not be universal, and the attractiveness of safe haven assets can vary over time. Secondly, the controversies behind using one asset over an another can be as a result of varying methodological studies having different conclusions as of an effectiveness of one asset. For COVID-19, it can't be stressed enough that the driving forces for financial crisis were totally different from earlier crisis and as such, effective asset for safe haven and hedge against equity markets could be unique question as well.

This thesis's results show that there are open questions around safe haven assets during the financial crisis of COVID-19. Statistically, only Bitcoin indicated some form of role as safe haven attributes for 1% bottom quantile of S&P 500 and oil for 10% bottom quantile. Both assets were observed to be statistically significant, but both did so with high coefficient. This however does not provide strong evidence for overall bitcoin's ability to act as safe haven asset with only limited number of observations (n=5) for this quantile in addition to fact that Bitcoin presented returns with high deviation from mean and overall poor performance during the financial crisis. For the oil, the answer is simpler, as the number of observations is higher (n=50), but still not noticeable high. The underlying thesis regarding oil's role as a safe haven is based on realized supply and demand and as such, lower price volatility.

However, only bonds act as hedge with negative correlation with S&P 500. Other assets with positive correlation values can't be considered as hedging assets. Such implications point that possible one of the most traditional asset class is still a valid protection for investors to cover their portfolio during times of market distress. Thus, access to such instruments is important. In this case, financial innovations of bitcoin and blockchain have not succeed in replacing or substituting other financial products, such as bonds.

Table 5 Summary of thesis hypothesis

H1: The Bitcoin does present itself as an ineffective hedge against the S&P 500 stock market index during COVID-19.	Confirmed
H2: The gold does present itself as an effective hedge against the S&P 500 stock market index during COVID-19.	Rejected
H3: The oil does present itself as an ineffective hedge against the S&P 500 stock market index during COVID-19 market.	Confirmed
H4: U.S. Treasure bonds does present itself as a hedge against the S&P 500 stock market index during COVID-19 market.	Confirmed

There are number of reasons why investors should pay attention to hedging abilities of different assets in times of financial distress. Firstly, in order to protect portfolios with recognised safe haven assets; Secondly, diversify from riskier assets to stabilize unexpected variation in returns and thirdly, psychologically, and behaviourally. Acknowledging that investment portfolio is protected by market downturns can limit the possible number of impulsive trades and help investors to make more rational investment decisions.

For future research, topic should be explored further with larger data set from developed and developing countries as well as potentially time-varying aspects in development of COVID-19 deaths and hospitalisation. Additional research topics could cover other non-financial crisis such as Russo-Ukraine war of 2022 or China-Taiwan conflict from the point of hedging portfolios.

References

Aggarwal, R., & Lucey, B. M. (2007). Psychological barriers in gold prices?. *Review of Financial Economics*, *16*(2), 217-230.

Ahn, D. H., Boudoukh, J., Richardson, M., & Whitelaw, R. F. (2002). Partial adjustment or stale prices? Implications from stock index and futures return autocorrelations. *The Review of Financial Studies*, *15*(2), 655-689.

Akhtaruzzaman, M., Boubaker, S., Lucey, B. M., & Sensoy, A. (2021). Is gold a hedge or a safe-haven asset in the COVID–19 crisis?. *Economic Modelling*, *102*, 105588.

Arouri, M. E. H., Lahiani, A., & Nguyen, D. K. (2011). Return and volatility transmission between world oil prices and stock markets of the GCC countries. *Economic Modelling*, *28*(4), 1815-1825.

Batten, J. A., Kinateder, H., Szilagyi, P. G., & Wagner, N. F. (2021). Hedging stocks with oil. *Energy Economics*, *93*, 104422.

Baur, D. G., & Lucey, B. M. (2009). Flights and contagion—An empirical analysis of stock–bond correlations. *Journal of Financial stability*, *5*(4), 339-352.

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*(2), 217-229.

Baur, D. G., & McDermott, T. K. (2010). Is gold a safe haven? International evidence. *Journal of Banking & Finance*, *34*(8), 1886-1898.

Baur, D. G., & Glover, K. J. (2012). The destruction of a safe haven asset?. *Available at SSRN 2142283*.

Baur, D. G., Hong, K., & Lee, A. D. (2018). Bitcoin: Medium of exchange or speculative assets?. *Journal of International Financial Markets, Institutions and Money*, *54*, 177-189.

Baur, D. G., & Hoang, L. (2021). The Bitcoin gold correlation puzzle. *Journal of Behavioral and Experimental Finance*, *32*, 100561.

Baur, D. G., Hoang, L. T., & Hossain, M. Z. (2022). Is Bitcoin a hedge? How extreme volatility can destroy the hedge property. *Finance Research Letters*, *47*, 102655.

Bashiri Behmiri, N., & Pires Manso, J. R. (2013). Crude oil price forecasting techniques: a comprehensive review of literature. *Available at SSRN 2275428*.

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*, 16-24.

Bekiros, S., Boubaker, S., Nguyen, D. K., & Uddin, G. S. (2017). Black swan events and safe havens: The role of gold in globally integrated emerging markets. *Journal of International Money and Finance*, *73*, 317-334.

BitMEX. (2020). *How we are responding to the 13 March ddos attacks.* Retrieved July 6, 2022, from https://blog.bitmex.com/how-we-are-responding-to-last-weeks-ddos-attacks/

Bouri, E., Molnár, P., Azzi, G., Roubaud, D., & Hagfors, L. I. (2017a). On the hedge and safe haven properties of Bitcoin: Is it really more than a diversifier?. *Finance Research Letters*, *20*, 192-198.

Bouri, E., Gupta, R., Tiwari, A. K., & Roubaud, D. (2017b). Does Bitcoin hedge global uncertainty? Evidence from wavelet-based quantile-in-quantile regressions. *Finance Research Letters*, *23*, 87-95.

Bouri, E., Gkillas, K., & Gupta, R. (2020a). Trade uncertainties and the hedging abilities of Bitcoin. *Economic Notes*, *49*(3), e12173.

Board of Governors of the Federal Reserve System (US), Market Yield on U.S. Treasury Securities at 10-Year Constant Maturity, Quoted on an Investment Basis [DGS10], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/DGS10, January 31, 2023.

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

Brandt, M. W., & Santa-Clara, P. (2006). Dynamic portfolio selection by augmenting the asset space. *The journal of Finance*, *61*(5), 2187-2217.

Capie, F., Mills, T. C., & Wood, G. (2005). Gold as a hedge against the dollar. *Journal of International Financial Markets, Institutions and Money*, *15*(4), 343-352.

Campbell, R., Koedijk, K., & Kofman, P. (2002). Increased correlation in bear markets. *Financial Analysts Journal*, *58*(1), 87-94.

Cheah, E. T., & Fry, J. (2015). Speculative bubbles in Bitcoin markets? An empirical investigation into the fundamental value of Bitcoin. *Economics letters*, *130*, 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?. *Available at SSRN 3590015*.

Chu, J., Zhang, Y., & Chan, S. (2019). The adaptive market hypothesis in the high frequency cryptocurrency market. *International Review of Financial Analysis*, *64*, 221-231.

Chui, C. M., & Yang, J. (2012). Extreme correlation of stock and bond futures markets: international evidence. *Financial Review*, *47*(3), 565-587.

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*, 101248.

Conlon, T., & McGee, R. (2020). Safe haven or risky hazard? Bitcoin during the COVID-19 bear market. *Finance Research Letters*, *35*, 101607.

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

Corbet, S., Hou, Y. G., Hu, Y., Larkin, C., & Oxley, L. (2020). Any port in a storm: Cryptocurrency safe-havens during the COVID-19 pandemic. *Economics Letters*, *194*, 109377.

Corbet, S., Hou, Y., Hu, Y., Lucey, B., & Oxley, L. (2021). Aye Corona! The contagion effects of being named Corona during the COVID-19 pandemic. *Finance Research Letters*, *38*, 101591.

Cruz-Reyes, L., Medina Trejo, C., López Irrarragorri, F., & Gómez Santillán, C. G. (2014). A decision support system framework for public project portfolio selection with argumentation theory. In *Recent advances on hybrid approaches for designing intelligent systems* (pp. 467-479). Springer, Cham.

Dale, C. (1981). The hedging effectiveness of currency futures markets.

Dutta, A., Bouri, E., & Noor, M. H. (2018). Return and volatility linkages between CO2 emission and clean energy stock prices. *Energy*, *164*, 803-810.

Dyhrberg, A. H. (2016a). Bitcoin, gold and the dollar–A GARCH volatility analysis. *Finance Research Letters*, *16*, 85-92.

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

Engle, R. (2002). Dynamic conditional correlation: A simple class of multivariate generalized autoregressive conditional heteroskedasticity models. *Journal of Business & Economic Statistics*, *20*(3), 339-350.

Fabozzi, F. J. (2010). Bond Markets, Analysis & Strategies. Pearson Education.

Fama, E. F. (1970). Session topic: stock market price behavior. *The Journal of Finance*, *25*(2), 383-417.

Federal Reserve Bank of St. Louis, St. Louis Fed Financial Stress Index [STLFSI4], retrieved from FRED, Federal Reserve Bank of St. Louis; https://fred.stlouisfed.org/series/STLFSI4, January 31, 2023.

Filis, G., Degiannakis, S., & Floros, C. (2011). Dynamic correlation between stock market and oil prices: The case of oil-importing and oil-exporting countries. *International review of financial analysis*, *20*(3), 152-164.

Gates, B. (2020). Responding to Covid-19—a once-in-a-century pandemic?. *New England Journal of Medicine*, *382*(18), 1677-1679.

Grobys, K. (2021). When Bitcoin has the flu: On Bitcoin's performance to hedge equity risk in the early wake of the COVID-19 outbreak. *Applied Economics Letters*, *28*(10), 860-865.

Hamilton, J. D. (2009). Understanding crude oil prices. *The energy journal*, *30*(2).

Hammoudeh, S. M., Yuan, Y., McAleer, M., & Thompson, M. A. (2010). Precious metals–exchange rate volatility transmissions and hedging strategies. *International Review of Economics & Finance*, *19*(4), 633-647.

Haber, S., & Stornetta, W. S. (1990, August). How to time-stamp a digital document. In *Conference on the Theory and Application of Cryptography* (pp. 437-455). Springer, Berlin, Heidelberg.

Harvey, C. R., Liechty, J. C., Liechty, M. W., & Müller, P. (2010). Portfolio selection with higher moments. *Quantitative Finance*, *10*(5), 469-485.

Hasan, M. B., Hassan, M. K., Rashid, M. M., & Alhenawi, Y. (2021). Are safe haven assets really safe during the 2008 global financial crisis and COVID-19 pandemic?. *Global Finance Journal*, *50*, 100668.

Hood, M., & Malik, F. (2013). Is gold the best hedge and a safe haven under changing stock market volatility?. *Review of Financial Economics*, *22*(2), 47-52.

Ilmanen, A. (2003). Stock-bond correlations. *The Journal of Fixed Income*, *13*(2), 55-66.

Ivanov, S. I. (2013). The influence of ETFs on the price discovery of gold, silver and oil. *Journal of Economics and Finance*, *37*(3), 453-462.

Ji, Q., Zhang, D., & Zhao, Y. (2020). Searching for safe-haven assets during the COVID-19 pandemic. *International Review of Financial Analysis*, *71*, 101526.

Jones, C. M., & Kaul, G. (1996). Oil and the stock markets. *The journal of Finance*, *51*(2), 463-491.

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*, 255-280.

Khuntia, S., & Pattanayak, J. K. (2018). Adaptive market hypothesis and evolving predictability of bitcoin. *Economics Letters*, *167*, 26-28.

Kim, T. (2017). On the transaction cost of Bitcoin. *Finance Research Letters*, *23*, 300-305.

Klein, T. (2017). Dynamic correlation of precious metals and flight-to-quality in developed markets. *Finance Research Letters*, *23*, 283-290.

Klein, T., Thu, H. P., & Walther, T. (2018). Bitcoin is not the New Gold–A comparison of volatility, correlation, and portfolio performance. *International Review of Financial Analysis*, *59*, 105-116.

Kristoufek, L. (2020). Grandpa, grandpa, tell me the one about Bitcoin being a safe haven: Evidence from the COVID-19 pandemics. *arXiv preprint arXiv:2004.00047*.

Kristoufek, L. (2020b). Bitcoin and its mining on the equilibrium path. *Energy Economics*, *85*, 104588.

Köchling, G., Müller, J., & Posch, P. N. (2019). Does the introduction of futures improve the efficiency of Bitcoin?. *Finance Research Letters*, *30*, 367-370.

Stoll, H. R. (2000). Presidential address: friction. *The Journal of Finance*, *55*(4), 1479-1514.

Lavelle, B., Yamamoto, K. N., & Kinnen, M. (2022). Cryptocurrencies, Correlations, and COVID-19: Diversifiers, Hedge, or Safe Haven?. *Review of Integrative Business and Economics Research*, *11*(2), 25-35.

Le Tran, V., & Leirvik, T. (2020). Efficiency in the markets of crypto-currencies. *Finance Research Letters*, *35*, 101382.

Lo, A. W. (2004). The adaptive markets hypothesis: Market efficiency from an evolutionary perspective. papers. ssrn. com.

Li, L. (2002). Macroeconomic factors and the correlation of stock and bond returns. *Available at SSRN 363641*.

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*, 285-294.

Ling, S., & McAleer, M. (2003). Asymptotic theory for a vector ARMA-GARCH model. *Econometric theory*, *19*(2), 280-310.

Lucey, B. M., & Li, S. (2015). What precious metals act as safe havens, and when? Some US evidence. *Applied Economics Letters*, *22*(1), 35-45.

Li, S., & Lucey, B. M. (2017). Reassessing the role of precious metals as safe havens–What colour is your haven and why?. *Journal of Commodity Markets*, *7*, 1-14.

Ma, R., Sun, B., Zhai, P., & Jin, Y. (2021). Hedging stock market risks: Can gold really beat bonds?. *Finance Research Letters*, *42*, 101918.

Mariana, C. D., Ekaputra, I. A., & Husodo, Z. A. (2021). Are Bitcoin and Ethereum safe-havens for stocks during the COVID-19 pandemic?. *Finance research letters*, *38*, 101798.

Markowitz, H. (1952). Portfolio Selection. The Journal of Finance, 7(1), 77–91. https://doi.org/10.2307/2975974

Nakamoto, S. (2008). Bitcoin. *A peer-to-peer electronic cash system*.

Nguyen, D. K., Sensoy, A., Sousa, R. M., & Uddin, G. S. (2020). US equity and commodity futures markets: Hedging or financialization?. *Energy Economics*, *86*, 104660.

Nguyen, K. Q. (2021). The correlation between the stock market and Bitcoin during COVID-19 and other uncertainty periods. *Finance Research Letters*, 102284.

Papadamou, S., Fassas, A. P., Kenourgios, D., & Dimitriou, D. (2021). Flight-to-quality between global stock and bond markets in the COVID era. *Finance Research Letters*, *38*, 101852.

Platt, E., & Carnevali, D. (2020, November 14). Inflows into stock funds hit 20-year high. Financial Times. Retrieved March 12, 2023, from https://www.ft.com/content/91cb3990-7ace-41f0-9939-d7fe8d0cab02

Salisu, A. A., Vo, X. V., & Lucey, B. (2021). Gold and US sectoral stocks during COVID-19 pandemic. *Research in International Business and Finance*, *57*, 101424.

Shalal, A. (2022). IMF sees cost of COVID pandemic rising beyond $12.5 trillion estimate. Retrieved 7 May 2022, from https://www.reuters.com/business/imf-sees-cost-covid-pandemic-rising-beyond-125-trillion-estimate-2022-01-20/

Sifma Research Quarterly – 1Q22. (n.d.). Retrieved May 8, 2022, from https://www.sifma.org/wp-content/uploads/2022/01/US-Research-Quarterly-Fixed-Income-Issuance-Trading-2022-04-26-SIFMA.pdf

Sumner, S., Johnson, R., & Soenen, L. (2010). Spillover effects among gold, stocks, and bonds. *Journal of centrum Cathedra*, *3*(2), 106-120.

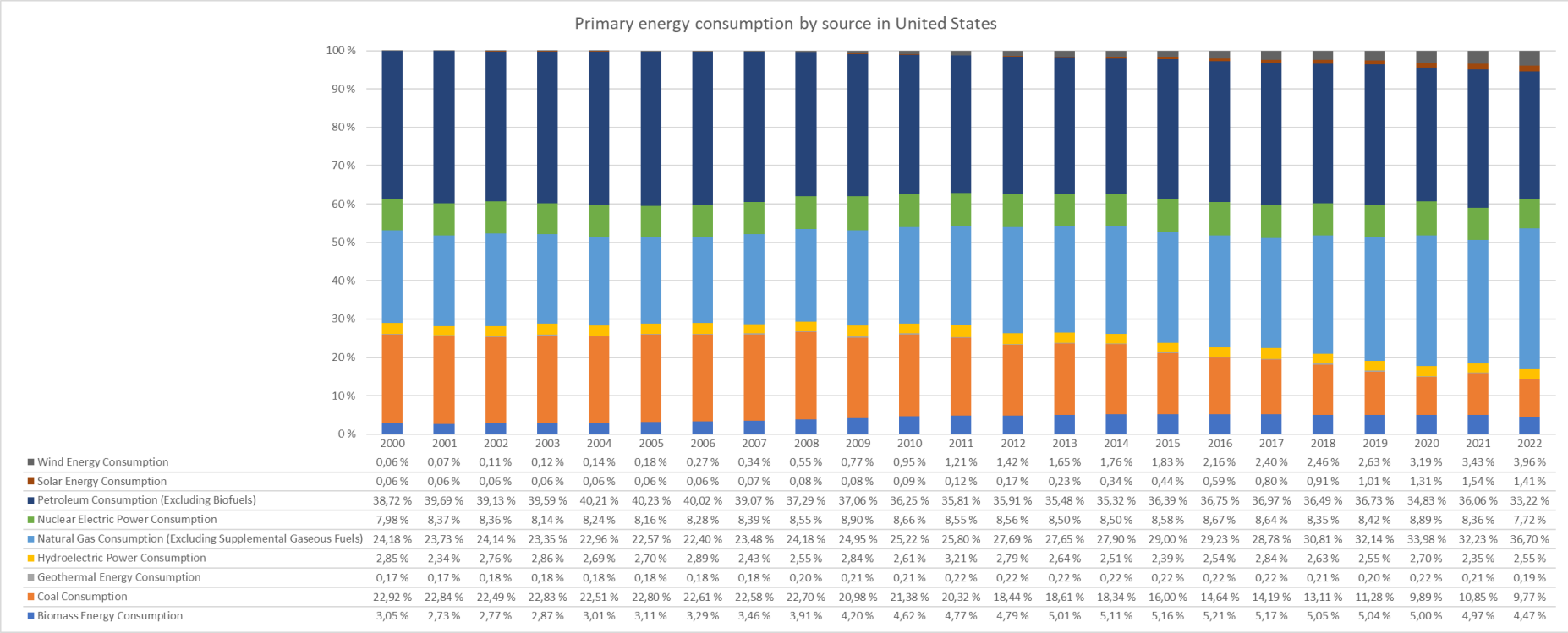
Taleb, N.: The Black Swan: The Impact of the Highly Improbable, 2nd edn. Penguin Book, London (2009)

Tarchella, S., & Dhaoui, A. (2021). Chinese jigsaw: Solving the equity market response to the COVID-19 crisis: Do alternative asset provide effective hedging performance?. *Research in International Business and Finance*, *58*, 101499.

U.S. Energy Information Administration (2022). Oil and petroleum products explained. Retrieved from https://www.eia.gov/energyexplained/oil-and-petroleum-products/imports-and-exports.php

Appendix

Appendix 1 Primary energy consumption by source in the USA



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Wind Energy Consumption	0,06 %	0,07 %	0,11 %	0,12 %	0,14 %	0,18 %	0,27 %	0,34 %	0,55 %	0,77 %	0,95 %	1,21 %	1,42 %	1,65 %	1,76 %	1,83 %	2,16 %	2,40 %	2,46 %	2,63 %	3,19 %	3,43 %	3,96 %
Solar Energy Consumption	0,06 %	0,06 %	0,06 %	0,06 %	0,06 %	0,06 %	0,06 %	0,07 %	0,08 %	0,08 %	0,09 %	0,12 %	0,17 %	0,23 %	0,34 %	0,44 %	0,59 %	0,80 %	0,91 %	1,01 %	1,31 %	1,54 %	1,41 %
Petroleum Consumption (Excluding Biofuels)	38,72 %	39,69 %	39,13 %	39,59 %	40,21 %	40,23 %	40,02 %	39,07 %	37,29 %	37,06 %	36,25 %	35,81 %	35,91 %	35,48 %	35,32 %	36,39 %	36,75 %	36,97 %	36,49 %	36,73 %	34,83 %	36,06 %	33,22 %
Nuclear Electric Power Consumption	7,98 %	8,37 %	8,36 %	8,14 %	8,24 %	8,16 %	8,28 %	8,39 %	8,55 %	8,90 %	8,66 %	8,55 %	8,56 %	8,50 %	8,50 %	8,58 %	8,67 %	8,64 %	8,35 %	8,42 %	8,89 %	8,36 %	7,72 %
Natural Gas Consumption (Excluding Supplemental Gaseous Fuels)	24,18 %	23,73 %	24,14 %	23,35 %	22,96 %	22,57 %	22,40 %	23,48 %	24,18 %	24,95 %	25,22 %	25,80 %	27,69 %	27,65 %	27,90 %	29,00 %	29,23 %	28,78 %	30,81 %	32,14 %	33,98 %	32,23 %	36,70 %
Hydroelectric Power Consumption	2,85 %	2,34 %	2,76 %	2,86 %	2,69 %	2,70 %	2,89 %	2,43 %	2,55 %	2,84 %	2,61 %	3,21 %	2,79 %	2,64 %	2,51 %	2,39 %	2,54 %	2,84 %	2,63 %	2,55 %	2,70 %	2,35 %	2,55 %
Geothermal Energy Consumption	0,17 %	0,17 %	0,18 %	0,18 %	0,18 %	0,18 %	0,18 %	0,18 %	0,20 %	0,21 %	0,21 %	0,22 %	0,22 %	0,22 %	0,22 %	0,22 %	0,22 %	0,22 %	0,21 %	0,20 %	0,22 %	0,21 %	0,19 %
Coal Consumption	22,92 %	22,84 %	22,49 %	22,83 %	22,51 %	22,80 %	22,61 %	22,58 %	22,70 %	20,98 %	21,38 %	20,32 %	18,44 %	18,61 %	18,34 %	16,00 %	14,64 %	14,19 %	13,11 %	11,28 %	9,89 %	10,85 %	9,77 %
Biomass Energy Consumption	3,05 %	2,73 %	2,77 %	2,87 %	3,01 %	3,11 %	3,29 %	3,46 %	3,91 %	4,20 %	4,62 %	4,77 %	4,79 %	5,01 %	5,11 %	5,16 %	5,21 %	5,17 %	5,05 %	5,04 %	5,00 %	4,97 %	4,47 %