JÖNKÖPING UNIVERSITY
Jönköping International
Business School

The Influence of Gold Market on Bitcoin Prices

Is there a correlation?

MASTER DEGREE PROJECT THESIS WITHIN:
Business Administration - Finance
NUMBER OF CREDITS: *15 ECTS*
PROGRAMME OF STUDY: *International Financial Analysis*
AUTHOR: *Kasra Shariati*
JÖNKÖPING May 2022

Master Thesis Project in Business Administration

Title: The Influence of Gold Market on Bitcoin Prices
Authors: Kasra Shariati
Tutor: Pär Sjölander
Date: 2022-05-19

Key terms: Bitcoin, Gold, Investor Attention, Market Performance, Virtual Currency Development, Investments, Correlation

---

Abstract

Background: This paper analyses the influence of fluctuation in gold market on bitcoin prices. Based on previous studies, in present market conditions, volatility in gold prices have caused price changes in several other major assets in the market, such as crude oil. Gold fluctuations are likely to stimulate uncertainty in some other major assets. As bitcoin is becoming an alternative tool to hedge against inflation likewise to gold, the degree of uncertainty in bitcoin market is relatively high. Therefore, the study of causal relationship between gold and bitcoin markets has become appropriate since bitcoin has tremendous growth in its returns and shares many similarities with gold. Thereupon, this study reveals the evidence of Granger causality regression in different time spans to understand the relationship between gold and bitcoin. This relationship is beneficial to study since Granger causality hypothesis acknowledges whether gold's historical prices are useful for forecasting the bitcoin market.

Purpose: This study aims to analyze the relationship between gold and bitcoin market during an 8-year period from 2014 and 2022. Throughout this period, time spans which involves financial crises have been separated from the data set and tested separately to determine if there is a constant relationship between the variables. Through this, it has been intended to find the Granger causality link between gold and bitcoin market to see whether one is leading another one. Identifying the Granger causality correlation helps analyzing the patterns of correlation by using the empirical datasets, and to determine the strength of the Granger causal relationship's nature between gold and bitcoin. Since the correlation itself does not explain why or how, but only if both markets move together, the Granger causality correlation between gold and bitcoin is the quantification of the impact that gold market performance has on bitcoin's future price performance.

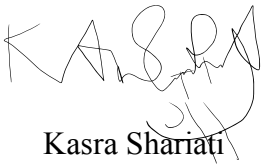
Method: Since the collected data is time-series data, Augmented Dickey-Fuller tests have been conducted initially to the chosen tests. Following the results from ADF tests, Spearman's Rho,

and Johansen's Cointegration tests have been utilized to determine the long-term correlation between variables. Thereafter, Toda & Yamamoto and Dolado & Lütkepohl Granger Causality (TYDL-GC) method has been used to analyze the Granger causality link between the variables. **Conclusion:** The results of this study indicates that (i) no statistically significant correlation between gold and bitcoin market has been found according to the Spearman's Rho test results, (ii) no long-term relationship has been found between gold and bitcoin according to cointegration test, (iii) gold does Granger Cause bitcoin prices. The evidence of causality link is unilateral from gold towards bitcoin market. Furthermore, it was observed that the Granger causality link weakens in short term and is not constant over time. The results fail to support the semi strong Efficient Market Hypothesis form. Thus, gold and bitcoin's markets are efficient in the weak form but inefficient in the semi strong form. Since Granger causality has been found from gold towards bitcoin, one can construct a prediction model for bitcoin by using gold's historical prices.

Acknowledgments

I would like to express my gratitude to everyone who has supported and encouraged me during this thesis process. First, I would like to express my sincere gratitude to Pär Sjölander for his guidance with the methodology and supervision. Second, I would also want to thank Kristofer Månsson for his insightful feedback.

With warmest regards from Jönköping, Sweden.



Kasra Shariati

Table of Contents

1. Introduction 1

1.1 Problem 3

1.2 Purpose 3

1.3 Perspective 4

1.4 Delimitation 4

1.5 Definition 4

1.5.1 Hedge 4

1.5.2 Safe haven 5

2. Literature Review 6

2.1 History of Gold 6

2.2 Bitcoin 8

2.3 Development of Gold Prices and Bitcoin Exchange Rates 10

2.4 Random Walk Theory 13

3. Methodology 16

3.1 Spearman's Rho Correlation Coefficient 18

3.2 Johnson Cointegration 18

3.3 Toda & Yamamoto and Dolado & Lütkepohl Granger Causality (TYDL-GC) 20

4. Analysis and Results 22

4.1 Spearman's Rho Test Results 22

4.2 Johansen's Cointegration & ADF Test Results 23

4.3 Toda & Yamamoto and Dolado & Lütkepohl Granger Causality (TYDL-GC) Test Results 26

4.3.1 Short-term and Long-term Causality Link 26

4.3.2 Whole Sample 27

4.3.3 The 2015 Financial Crisis 27

4.3.4 The COVID-19 Crisis 28

5. Conclusion and Discussion 29

Reference list 31

Appendices 44

Appendix 1 Normality Test 44

Appendix 2 ADF Stationary Test 45

Appendix 3 First Order Difference 45

Appendix 4 Spearman's Rho Test 46

Appendix 5 Johansen's Cointegration Test 46

Appendix 6 Toda & Yamamoto and Dolado & Lütkepohl Granger Causality Test (TYDL-GC) 47

Appendix 7 Inverse Roots 49

List of Figures

Figure 1. Price Development....12
Figure 2 Price Development....13

List of Tables

Table 1: Descriptive statistics 17
Table 2: Spearman's Rho on return 22
Table 3: Unit root test at level....23
Table 4: Unit root test at 1st difference....23
Table 5: Johansen's cointegration test 24
Table 6: TYDL-GC test 26

1. Introduction

This chapter introduce the general overview of the role of gold and Bitcoin within the economy and for investors, followed by the purpose and problem discussion on the research question.

Gold has despite the creation of cryptocurrencies and currency digitalization been known as the safe haven (type of investment which retain or increase value during market turbulence) for investments as it carried lower risks and had high returns (Harris & Shen, 2017; Ji et al., 2020). Even though many economists argue that the value of gold is nothing but just a bubble, yet many investors tend to be apathetic and not believe that gold was overvalued. Gold has always been known as an economic property in the market since investors could hedge their portfolio with gold against currency risks, inflation, and during crisis (Beckmann & Czudaj, 2013; Capie et al., 2005; Baur & Lucey, 2010). Throughout history, gold has been used as a safe haven and low risk asset for various reasons. Gold had for decades been the basis of the monetary systems in many countries (Bordo et al., 2019). After the use of gold has been ceased and replaced by money, gold has become a commodity in the market for investments. Today, one can invest in gold by buying gold miners stocks, exchange traded funds (ETFs), or buying gold as physical material. Thus, it is beneficial to point out why gold has been an inevitably valuable hedge while it was used in the monetary system, and to explore why it remained a hedge thereafter. Being known as a safe haven made gold traditionary asset to hedge portfolio against volatile markets and uncertainty within investors (Agyei-Ampomah et al., 2014). Nevertheless, one can say since the appearance of bitcoin in the market, the popularity of gold for investors has been diminished due to bitcoin's high returns. In the last decade, investors are leaning towards bitcoin as the return on bitcoin is hundredfold more compared with gold (Ozturk, 2020). Despite bitcoin prices having a greater volatility in short-term compared with gold prices, bitcoin's price development is likely to remain upwards in the long-term alike gold's price development (Dyhrberg, 2016). Moreover, as the world is moving towards digitalization, the use of traditional currencies and physical money are becoming less popular. As Milton Friedman, who won the Nobel prize in economics in 1976, stated "The one thing that's missing but that will soon be developed

is a reliable e-cash, a method whereby on the internet you can transfer funds from A to B without A knowing B or B knowing A, the way in which I can take a twenty-dollar bill and hand it over to you and there is no record of where it came from and you may get that without knowing who I am" (Laboure & Reid, 2020). Due to mentioned above, many believe that bitcoin share some properties with gold prices and there is a strong relationship between both assets. All things considered, one may question whether bitcoin is following gold prices or not?

Many economists and investors argue the existence of the correlation between bitcoin and gold and debate which asset they must take into consideration when investing. Nevertheless, as many are studying the bitcoin behavior in the market and trying to analyze and understand its movement, there were many studies on bitcoin behavior compared with various assets in the market. Hence, the relationship between bitcoin and gold remains largely unexplored that whether the in sample, for instance, coexistent and therefore predictability, relationship between the bitcoin prices and gold exchange rate determinants effectively translates in the direction of out of sample non predictive of the gold exchange rates. The possibilities of replacement of gold in the economy by bitcoin has also received relatively little attention in academia. Thus, the purpose of this research is to investigate the empirical relationship between bitcoin prices and the gold exchange rate, where both rates of bitcoin and gold prices are expressed in US dollar. This study suggests to analyze the empirical relation between both assets via a Cointegration regression method, which is known as the optimum quantitative technique to analyze the correlation between two variables during a specific time period (Beck, 1992). This procedure will be applied on weekly frequency data during an 8-year period between January 2014 and January 2022. Additionally, different time periods within the main sample have been analyzed to evaluate whether the relationship is constant or not. The chosen periods are 2015-2016, when the Brazilian financial crisis and Chinese stock market crash affected the world's economy (Franzotti & Valle, 2020; Wang & Hui, 2018), and 2020 when economic recession occurred due to the COVID-19 pandemic (Yancey & Krome, 2021). All the quantitative data has been collected via the Saxo Bank trading platform as well as Yahoo Finance. Moreover, the raw data will be processed with EViews programming econometrics software.

To receive a better understanding of this investigation on bitcoin and gold, the following researched question was developed, *Is there a positive correlation between bitcoin and gold's prices?*

1.1 Problem

Despite various illusional beliefs in the market which attempts to address the correlation or relationship between bitcoin and many other assets such as Tesla, S&P500, etc., the feasibility of the correlation between bitcoin and gold appears to be more rational and believable (Baur & Hoang, 2021; Doumenis et al., 2021; Hung, 2022). The primary problem of this research alludes to illustrate if there is any correlation between bitcoin and gold in the market, and more importantly, if there is a possibility of predicting bitcoin by using gold's historical dataset in the economy. Thus, the question is what the relationship between bitcoin and gold is, or to clarify if there is any relationship between both variables at all. As the Granger causality illustrates that the presence of one event may influences another, then one could be able to benefit from understanding the Granger causality direction, since Granger cause discovery help to improve the understanding of the market movements. In the case of finding a correlation between the mentioned assets, one may be able to forecast bitcoin prices by using gold's historical prices, which can be beneficial for both investors and economists.

1.2 Purpose

The purpose of this thesis is to investigate and analyze the relationship between bitcoin and gold; based on their behavior and correlation with another, by developing the following hypothesis:

- Hypothesis H0: Does gold market Granger Cause bitcoin prices?
- Hypothesis H1: Gold market does not Granger Cause bitcoin prices.

1.3 Perspective

This research will be conducted with the aim of answering the research question from a macroeconomic perspective. Moreover, the result of the study can be beneficial for other sectors as well, e.g., private sectors, investors, corporations, etc. The taken assets for this study are traded by governmental sections as well as individuals and independent traders.

1.4 Delimitation

This section shines a light on the areas which will not be covered in the research. To begin with, the use of assets as a treasury for governments is a very specific and exclusively independent topic for different governments and regimes, which requires deep and intensive research. Therefore, this paper will only discuss the possibility of using bitcoin as a treasure in general and point out the possible advantage and disadvantages of doing so. Thus, the main purpose of the research is to determine whether gold prices lead bitcoin market or not.

1.5 Definition

The analytical arguments, which are the base for the consecutive study can be explained as follows: By adding an asset to an investor's portfolio, there will be a reduction of losses in times of market stress and turmoil. The severity of shocks decreases by additional hedge or diversifier assets, thereby this increases the stability of capital markets. For the sake of distinguishing a hedge from a safe haven, both types of assets have been defined below:

1.5.1 Hedge

A hedge is an asset which is uncorrelated or has a negative correlation with other assets or holding portfolio on average. Moreover, a hedge does not play a significant role in the times of market stress or turmoil (crises) since it can be highly affected by them (Beckmann et al., 2015).

1.5.2 Safe haven

A safe haven is an asset which is uncorrelated or has a negative correlation with other assets or holding portfolios in the occasion of market stress or turmoil. Accordingly, in normal times, the asset can have both a positive and negative correlation. A safe haven asset can benefit the investor's portfolio by compensating the loss in extreme condition of the market by rises in the price of a safe haven asset. Therefore, safe haven offers a shield to investors in times of turmoil market conditions (Dimitriou et al., 2020).

2. Literature Review

This chapter begin with the state of current literature within the research topic and presents further insight on the relationship of gold and bitcoin. Furthermore, the reader will be provided with an overview of gold and bitcoin's development and their similarities.

For the purpose of identifying and assessing the appropriate academic literature in respect to the topic of correlation between gold and bitcoin, the author has taken a systematic approach to the subjected literature review with the aim to be objective as well as methodological. The conducted literature review aims to investigate and seek identification of the research critical elements by presenting previous literature regarding gold and bitcoin behavior. The selected literatures which are relevant to the topic have been found from online data bases such as "Primo" and "Google Scholar". The main searched key words have been utilized with the advanced filters while "peer reviewed journals" option has been selected. The selected key words were as follows: "gold behavior"," bitcoin behavior", "gold and bitcoin relationship". Although the topic of the paper is relevantly new in academia, a standard method on how to choose the best relevant articles was based on the publication date of the papers. Once reviewing the chosen articles, a decent and sufficient level of support was found in previous research concerning to focus on the topic against reliable list of relevant articles. Moreover, four themes were identified by the author based on the examination of the published literatures, which are history of gold, bitcoin, development of gold prices and bitcoin exchange rates, and the random walk theory.

2.1 History of Gold

"There can be no other criterion, no other standard than gold. Yes, gold which never changes, which can be shaped into ingots, bars, coins, which has no nationality, and which is externally and universally accepted as the unalterable fiduciary value par excellence.", said by Charles de Gaulle (Capie et al., 2005). For decades, gold had been the greatest

standard of value for many countries. Apart from this, gold was a standard which controlled constantly its purchasing power in respect to goods. For decades long, gold had been the base of the monetary systems if not used as money; thereupon, it ceased and turned into a commodity. Thus, one can say it is beneficial to explain why gold had been inevitably the best asset to hedge while it was the base of monetary system, and why it remained a hedge despite after these conditions revised. Holding gold as money or ground foundation for monetary systems implied to link gold with a currency at a fixed price. Which turn into losing control of prices by central banks and governments since the gold price was contingent with supply and demand in the market. Ceasing gold in monetary system did not mean that the asset no longer would be considered as a good store of value or a safeguard against volatile exchange rates or inflation. Meaning that still when a currency weakens, people tend to switch their capital to gold; contrary, when a currency become stronger, people switch from gold as they feel more confident about the currency's value (Capie et al., 2005; Joy, 2011; McGregor et al., 1981). Moreover, an increase in inflation or expected appreciation of gold price will make investors to buy gold and hedge gold in their portfolio against risk or in favor of return of appreciation. Which makes gold to be associated as an important economic property with economical phenomena such as inflation and currency risks, and designate gold as a safe haven in economies, especially during crises. (Beckmann & Czudaj, 2013). After all, one may question if it is still beneficial to invest in gold? For the sake of understanding the merits of investing in gold, one must analyze the performance of gold returns in previous years compared with market index. A study by Piñeiro-Chousa et al., (2018) shined a light on the performance of gold compared with S&P 500 index for a 5-year period. As the authors claimed, gold return has underperformed compared with S&P500 index as S&P500 generates significantly higher return compared with gold. Being said that gold has been performing fairly well until 2012; however, after that point, the return performance of gold has been diminished significantly while S&P 500 was performing contrariwise. Which can tell us that gold is not always the best investment in the market since market conditions changes as time goes (Piñeiro-Chousa et al., 2018). Yet, another study by Pho et al. (2021) shined a light on the higher returns of investments on bitcoin compared with gold (Pho et al., 2021). All in all, one could say that gold is not as tempting for investors as before, and one could benefit more by investing in a higher performing asset based on market conditions.

As gold has always been the center of attention in the market, there have been many studies and comparing methods to investigate gold behavior and correlation between gold and other major assets. For instance, a study by Shahbaz et al. (2017), compared the relationship between gold and crude oil market to analyze whether if gold Granger causes crude oil price or not. Moreover, the author found out that there is a high positive correlation between crude oil and gold prices (Shahbaz et al., 2017). The results of this study can be backed up by another study by Zhang and Wei (2010), which had the same result but for a different time period (Zhang & Wei, 2010). Furthermore, Guan et al. (2021) has conducted a study and drawn a conclusion which supports the existence of high correlation between gold and crude oil prices and if it has a direct effect on the economies and inflation (Guan et al., 2021). On the other hand, a study by Gopal & Munusamy (2016), has investigated the correlation between gold prices and USD exchange rates. The author has shown this relationship by conducting Granger causality test and claimed that gold price changes do Granger cause USD exchange rates (Gopal & Munusamy, 2016). The main outcomes of these empirical studies reveal the fact that in the previous research through history, gold did Granger cause other major assets and it could have a significant impact on bitcoin returns as well.

2.2 Bitcoin

Before investigating the relationship between bitcoin and gold, one must explain what bitcoin really is. In early 2008, when bitcoin was introduced to the market as a digital currency, the world of monetary system started to change. Satoshi Nakamoto who was the creator of bitcoin, launched this worthless digital coin for transaction and mining in 2009, which the first transaction took place in 2010, 10,000 coins for two slices of pizza in Florida, USA. As of today, bitcoin is known as the mother of all digital coins on the market and after publicity of bitcoin in the world, over 4,000 coins and tokens have been introduced to the market. Nevertheless, citing bitcoin's $700 billion market capitalization and peak price of over 68k per coin brough everyone's attention to this new phenomenon in the financial market. The high volatility and rapid jumps in bitcoin's prices made a great opportunity for investors worldwide. Additional to bitcoin's excessive market value, the simplicity of transaction and trade through decentralized technology and online

payment system boosted the popularity of bitcoin along other digital currencies (Litwack, 2015; Marella et al., 2020; Böhme et al., 2015; Sabalionis et al., 2020). Today, on the grounds that digitalization and new technologies are going viral, electronic financial systems are widely used. Moreover, one can say that bitcoin added several new features to these techs and made cryptocurrencies favorable in the market, and meanwhile, debatable. Debates and topics regarding bitcoin, if not the most widely spoken, it is indubitable one of the hottest topics in many sectors. This popularity has made bitcoin to be accepted as a payment and monetary system by some governments and cooperation. Yet, many lawmakers and governments are trying to challenge bitcoin's transactions (Huberman et al., 2017; Matei & Baks, 2019).

Bitcoin's massive value in growth and return has taken the world's attention, yet many argues about what is the impact of cryptocurrency or more specifically bitcoin, will be in today's economy. However, before arguing the impact of bitcoin on the economy, the relationship between both essential manners must be discussed. Enormous amounts of daily international trades are processed through various currencies which have different exchange rates. Trading with traditional currencies can cause some losses or gains for trades as the exchange rates between currencies are floating constantly and most likely, trader is obligated for transaction fees. In contrast, bitcoin has no transaction fee, and it is almost untaxed in many countries. Even though bitcoin is youthful in the market, yet the impact of bitcoin on the economy is a controversial topic in society (Everett, 2018; Grobys, 2020).

As one could imagine, the underlying value of bitcoin cannot be detected by dividend, cashflow, or monthly reports, instead, supply and demand dynamics are being used to determine the stock's value. Moreover, nothing constitutional can value the bitcoin network, likewise to any other fiat currencies. Nevertheless, one can say that banks do see bitcoin prices driving value in cryptocurrencies' network, mainly due to its scarcity and popularity. As Østbye (2018) found, there will be only 21 million digital coins of bitcoin in the market once the last coin is mined (Østbye, 2018). Moreover, the scarcity of bitcoin in the market sparks a surge on the bitcoin prices. Although bitcoin has no fundamental value nor physical object, bitcoin does not perish, nor it can be destroyed. The coins will survive and remain in the market as long as there is network in our

communities (Cheah & Fry, 2015). In the last decades, bitcoin has been presented as the "new gold" by social media, investment advisors, and many banks (Klein et al., 2018). This label can be motivated by the fast growth and high returns on bitcoin prices which is similar to gold. For that reason, the author has decided to compare gold and bitcoin from an econometric perspective and the focus has been set on the financial and economic aspects of bitcoin as an investment asset instead of gold. Previously, bitcoin was sometimes marked as common stocks due to the fact that bitcoin possess certain risk return of liquidity and legitimacy which ties bitcoin closer to the common stock classification (Alfieri et al., 2019; Baur et al., 2018; Glaser et al., 2014). Moreover, volatility of bitcoin prices has also spillover effects on commodities like gold as the return on bitcoin appears to be more beneficial for investors (Guesmi et al., 2018; Jareño et al., 2020).

2.3 Development of Gold Prices and Bitcoin Exchange Rates

Financial markets are often referred to be like rollercoasters, sometimes it goes up and sometimes it goes down. As the sharps fools are rising volatility in the markets over the last years, many riders wonder if they will make off in one piece. But the paralyze extend beyond the shared, appeal the adrenaline junkies as nukes go wide and stomach shred. The difference between a thrilling ride and a catastrophic ride is holding everything up. In order to understand the development of bitcoin and gold prices, one must understand the relationship between two assets as well as the similarities between both of them. To do so, first one must explain what the similarities between both assets are and more importantly, why the author believes that there could be any correlation between gold and bitcoin.

Virtual currencies, which also have been known as crypto or digital currencies e.g., bitcoin, are an emerging technology which are not governed nor controlled by any country or financial sector and yet has no fundamental values. One can say that the primary similarities between gold and bitcoin is that both assets have no nationality, and neither of them are controlled by any government (Capie et al., 2005; Brophy, 2019). Another argument is that even though gold may be known and act as an inflation hedge during a long period of time, the gold's price in short periods of time reveals a notable volatility

of gold prices, which is the same situation as for bitcoin (Beckmann & Czudaj, 2013; Matkovskyy & Jalan, 2020). Another arguable fact is that as mentioned previously, both assets are limited in the market and their prices soars due to their scarcity. This scarcity of both assets makes them more alike as each other. As bitcoin is taking away some market shares from gold and attentions are leaning towards bitcoin, one can see that both bitcoin and gold prices are raising towards the same direction during the uncertainties, as both assets are considered as safe havens during crisis. Thus, one may say that there is a possibility that gold could cause bitcoin's price movement (Baur & McDermott, 2009; Bouri et al., 2017; Urquhart & Zhang, 2018; Sarkodie et al., 2021). Additionally, as mentioned previously, the evidence of Granger causality from gold to other major assets such as crude oil and USD has been found by previous researchers. After all, the question has been addressed as if gold Granger cause bitcoin as well with regards to its correlation with bitcoin and its volatile behavior.

By comparing bitcoin with gold, one can say that both assets are durable, and bitcoin especially is easy to store and transfer all over the world, regardless of the amount of quantity of the coins. Contrary, gold is far more complicated and more costly to store and transport. As mentioned before, gold has been known as inflationary hedge over a long period of time, which makes gold the "holy grail of inflation" in the market. While on the other hand, bitcoin carries more risks due to its volatility (Troster et al., 2019). Thus, one can say gold may remain in favor when inflations are expected to last long. For instance, gold was a perfect preserver of purchasing power in 1970s, when inflation rate was above 6.8% and gold had a return of 16% (Barro & Misra, 2016). At the present time, the inflation rate in advanced economic countries is around 7.5% while no one can say if it is either transitory or not, gold hasn't responded to the inflation yet (Slater, 2022). Bitcoin on the other hand, had a massive return of 300% in 2020, which causes bitcoin to have an attracting market cap and siphoning some capital away from gold (Sarkodie et al., 2021). Thus, one may question that to what extend bitcoin will take market share away from gold in the future? As $875 billion market capitalization of bitcoin is nowhere comparable with numerous market capitalization of gold, which is over $2.6 trillion, one may say it is too early to say that the status of gold is threaten by bitcoin (Su et al., 2020; Yahoo Finance, n.d; World Gold Council, n.d.). Nevertheless, one could say that bitcoin

will indubitably become a larger proportion of the market over time as its return is enormously higher than gold's return.

To receive a greater understanding of the price development and movements of both assets, the graph below was constructed to point out the historical data of each asset.

Figure 1. Price Development

***Source**: Author's calculations*

Figure 1 represents the price development of gold and bitcoin from January 2017 to January 2022. Gold's price development is represented as a blue line with its price range on the right y-axis, and the orange line represents bitcoin's price developments with its range on the left y-axis. Remaining figures in this section are constructed accordingly as well. By eyeballing Figure 1, one can easily say that even though there is a great price difference between bitcoin and gold prices, both assets tend to move together and share the same movement structure. However, as seen in the figure, bitcoin experienced a massive volatility since the beginning of the COVID-19 pandemic in 2020 (Mahase, 2020). Figure 1 shows that as the pandemic continues, the volatility of bitcoin remains as well. Nonetheless, to receive a greater understanding of the pandemic period between 2020 and 2022, Figure 2 was created to gain additional insight of the market movements.

Figure 2 Price Development

***Source**: Author's calculations*

As it conspicuous in Figure 2 , both assets experienced high volatility when the COVID-19 pandemic occurred. Nevertheless, one can say that although both assets experienced high jumps and drops during this period, they tend to move towards the same direction. All in all, looking at the price movement could give a greater motivation to question whether the assets are correlated or not, and if they Granger cause another? Or to be more precise, one may ask does gold markets have a tendency to lead bitcoin?

2.4 Random Walk Theory

The random walk theory argues that price movements in the stock markets and securities are unpredictable. Moreover, the theory argues that investors may not be able to outperform the market as a whole frequently. The theory asserts that analyzing the market time is meaningless and leads to deterioration, and indexes are better replacements for the investors. The hypothesis of this theory is that it is impossible to surpass the market on a regular basis. And the asset prices are efficient due to their financial performance such as earnings, expectations, and dividends. Additionally, asset prices moves only when new financial information is revealed, and such information are random and unpredictable for investors. In another way, one can say that the theory suggests that any changes in asset prices have the same distribution and considered to be independent from each other. Meaning that history of the stock price or trend cannot be analyzed to predict future prices (Zvi Bodie et al., 2021; Zhu, 1998).

On the other hand, the non-random walk theory suggests that valuable information can be analyzed and extracted from the past movements. Lo et al. (2000) claimed that the historical movements of assets can be analyzed to predict future prices and valuable information can be conducted by evaluating historical movements of the market (Lo et al., 2000). Another study by Durusu-Ciftci et al. (2019) proves that although first- and second-generation panel of unit root tests show the existence of a non-random walk theory and the possibility of prediction of assets prices by past movement, cross section dependence panel in unit root test proves otherwise. As authors continues, the existence of random walk theory could be due to the fact that technical analysis cannot include all of the information to forecast future movements. For instance, positive/negative news in an industry or word of mouth from certain individuals can have a high effect on the price movement of an asset, and more importantly, may change the movement direction of the asset's price. Thus, the investors cannot predict returns that are higher than the market average by analyzing the historical movement of the assets (Luo, 2009; Durusu-Ciftci et al., 2019). As much as this is true, one can say that there are lots of factors which can affect the price movements of both assets, especially bitcoin. A study by Huynh (2021) shows that how a Twitter post from Elon Musk, the founder of Tesla Inc. can direct bitcoin prices and change the movement direction in the short time, but not in the long run (Huynh, 2022). The result of this study can be back up by the findings of Merkaš & Roška (2021) which shed a light on how strongly unsystematic information can have an impact on bitcoin prices in the short run (Merkaš & Roška, 2021). Moreover, one can say that gold price has not been neglected from unsystematic information. Hajek and Novotny (2022) claimed that news and unsystematic information has an impact on the gold market in the short run (Hajek & Novotny, 2022). Additionally, a study by Atri et al, (2021) shows how news regarding the COVID-19 pandemic affected the gold market and shed a light on the importance of social media and the trends on gold and other commodity prices (Atri et al., 2021). All in all, one can say that since both assets are trends in the market and have a bold status for investors, both are highly affected by word of mouth and news on the market in the short term, but not long. However, this does not necessarily mean that gold or bitcoin prices cannot be forecasted, nor it means that forecasting the assets based on their historical movement is meaningless. One can say that previous

studies has shown a successful future prediction of both bitcoin and gold prices based on analyzing their historical movements (Aggarwal, 2019; Shukor et al., 2021).

Since the 1960s, after presenting the Efficient Market Hypothesis by Eugene Fama, the EMH theory has been the center of the debates. Yet, the EMH theory is more prominent than ever since investors are more interested in diversification of their portfolios. Nevertheless, as the theory resulted in anomalies from time to time, the EMH theory has been criticized by investors since it has been introduced (LeBaron, 1999). Contrariwise, it was controversy within academia and investors that the EMH theory must be based on disequilibrium of the market. Theoretically, the EMH asserts that the price of an asset (stock, security, etc.) fully reflect all known information expeditiously and accurate. Moreover, Fama (1970) has defined the EMH theory into tree types which are weak, semi strong, and strong form of market efficiency (Fama, 1970). Weak form of EMH implies that the available information reflects solely on the history of price/return, meaning that investors will not be able to make abnormal profits and asset prices reveals a random walk process. In the semi strong form, EMH suggests that asset prices reflect the available information to all parties in the market. Lastly, the strong form states that asset prices reflect interior information additional to past prices and publicly accessible information (FAMA, 1991; Fama, 1970). A market considered efficient regarding to the information if asset prices are fully based on the information and traders cannot generate profit on this basis (Jensen, 1978). However, according to a study by Grosche (2014), existence of Granger causality in weekly and monthly data implies the rejection of a semi strong form of the EMH theory, which creates an investigation of the source of the market inefficiency. Nevertheless, an absence of Granger causality relationship between variables is considered as the consequence of semi strong market efficiency. Hence, an absence of Granger causality is a necessary condition for semi strong efficiency. Therefore, a rejection of the null hypothesis of no Granger causality indicates that the forecast on one asset price can be improved by using the other asset's historical price in the information sets (Brunetti et al., 2011; Grosche, 2014).

3. Methodology

This chapter begins with the details of the data used in this study and the descriptive analysis of the data. Thereupon, the methods used in this research considering testing for the results have been introduced.

As the aim of this research was to study the relationship between gold and bitcoin prices, the price history of both assets has been collected with weekly frequency for the 2014-2022 period. As the author believed, testing the consistency and stability of the correlation link between both assets during different time period helped the research to receive a greater insight of the assets' behavior as one can see in the result both long- and short-term. Thus, the tests have been conducted on different time spans during the chosen period to determine whether the results will vary in different time period. Both bitcoin and gold prices were extracted from Yahoo Finance and the SaxoBank platform using the open price of the first day of each week for the weekly taken period.

A quantitative research method was chosen for this paper since the aim of the research was to test whether there was a significant statistical correlation in the generated data. To present the relationship between the chosen assets, various analytical method was chosen to evaluate the relationship between bitcoin and gold market, and then used to analyze the relationship and possible effect of them on each other. Thus, to begin with, Spearman's Rho was chosen to find the monotonic relationship between both asset's markets. Following the result of the Spearman Rho Correlation, TYDL Granger Causality test was conducted to evaluate possible Granger causal link from one asset towards another. Lastly, as the collected data were non-stationary, cointegration test was performed as well to back up the result of a possible relationship between the assets in the long run. The following sections demonstrates deeply on what the methods contributed and why they were chosen.

	Weekly	Weekly
	Gold	**Bitcoin**
Mean	1442.125	9702.928
Median	1351.800	4088.000
Maximum	2098.500	64406.00
Minimum	1114.500	218.7000
Var	52315.4524	231103515
St.dev	228.7257	15202.09
Skewness	0.965180	2.171434
Kurtosis	2.682126	6.678929
Jarque-Bera	67.45679	570.9621
P-value	0.000000	0.000000
Number of Observation	423	423

Table 1: Descriptive statistics

***Source**: Author's calculations*

Table 1 illustrates the descriptive data statistics, Jarque Bera tests and other statistical data for all the variables in the sample period. As it can be seen in the table above, both the mean and the median of bitcoin are massively higher than gold for the analyzed data. However, by looking at the standard deviation, which illustrates the risk measure of the asset, one can say that bitcoin prices are considerably more volatile compared with gold prices. Moreover, both assets have excess kurtosis and Jarque Bera, with P-values that are less than 5% for all of them, which illustrates a non-normality distribution of the data. Additionally, as seen in Appendix 2, the p-value for all of the variables in the standard Augmented Dickey-Fuller (ADF) unit root test, are all above 5% significant level, meaning that non-stationary states have been confirmed and the variables have unit roots. Nevertheless, as Appendix 3 shows, the variables become stationary after taking the first

order difference since the p-value for the variables are below 5% significant level, which is the condition for the stationary state (Tam, 2012; Paparoditis & Politis, 2016).

3.1 Spearman's Rho Correlation Coefficient

The Spearman's rank correlation coefficient test is a non-parametric test which can determine the monotonic relationship between two variables. Moreover, as Spearman's Rho does not rely on normality of the data, one can say that it is not sensitive to non-normality. As Puth et al (2015) claimed, Spearman's Rho will be used when variables are not normally distributed. The strengths associated between the chosen variables can be defined by the given r value from the test result. Meaning that the closer as the value is to 1, the stronger positive correlation can be concluded from the result, and as closer the r value is to -1, the stronger negative correlation can be concluded in the result. Nonetheless, a r value of 0 denotes for no relationship between the variables. Moreover, the average rank of the variables in the Spearman test are equal to (n+1)/2 and can be calculated by using the following equation (Prion & Haerling, 2014; Puth et al., 2015):

$$r_s = \frac{\sum_{i=1}^{n}\{(x_i-\bar{x})(y_i-\bar{y})\}}{\sqrt{\sum_{i=1}^{n}(x_i-\bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i-\bar{y})^2}}$$

Which will yield the result as $-1 \leq r_s \leq 1$.

3.2 Johnson Cointegration

A cointegration test usually is being used in order to determine whether there is a correlation between time series variables in the long run. Nevertheless, Johansen's Cointegration likelihood test is usually taken to detect the co-integration rank between variables. Even though there are many existing methods in past literature, Johansen's cointegration method has been known as a useful method within econometrics and financial analysis (Larsson, 1997). Johansen's approach has become attractive in academia as it provides unified set of tools of estimation, cointegration analysis, and hypothesis testing based on the famous Autoregression model (VAR). Moreover, as the model tests for stationary state of the variable as well as estimating the optimal number

of lags for TYDL-GC test, it is the most used model in the literature (Kitamura, 1998). Additionally, Dickey-Fuller (ADF) unit root test has been tied to the autoregression model to evaluate linear trends in the variables. Furthermore, one can say that cointegration test implies in time series to identify scenarios and analyze if two or more non-stationary time series are integrated simultaneously in the long terms. The test can identify that two or more sets of variables are cointegrated if a linear combination of all of the taken variables have a lower order of integration. The Johansen's cointegration rank is:

$$\Delta X_t = \alpha\beta' X_{t-1} + \sum_{i=1}^{k-1} \tau_i \Delta X_{t-1} + \phi D_t + \epsilon_t$$

Where X is deterministic of vector series and α and β are p dimensional error (Johansen, 1988).

As the stationary condition is important in time series data and when using a Granger Causality method, one must ensure the stationarity state of the data to avoid spurious regression and bias, meaning that mean, variance, and covariance of the variables are time-invariant (Gujarati et al., 2012). To do so, as mentioned previously, ADF test will be conducted to detect if the time series have a unit root (Dickey & Fuller, 1979). The ADF test determine whether there is a unit root (stationarity) exists by testing if δ is significant in the following models:

Random walk:

$$\Delta Y_t = \delta Y_{t-1} + \sum_{i=1}^{m} \alpha_1 \Delta Y_{t-1} + \varepsilon_t$$

Random walk with drift:

$$\Delta Y_t = \beta_1 + \delta Y_{t-1} + \sum_{i=1}^{m} \alpha_1 \Delta Y_{t-1} + \varepsilon_t$$

Random walk with drift and trend:

$$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + \sum_{i=1}^{m} \alpha_1 \Delta Y_{t-1} + \varepsilon_t$$

Where β_1 and β_2 are drift parameters and parameters for trend (Gujarati et al., 2012).

3.3 Toda & Yamamoto and Dolado & Lütkepohl Granger Causality (TYDL-GC)

By analyzing at the previous literature and econometrics methods, one can say that Granger causality test by Granger's (1969) work, is one of the most popular tests for predictability of Granger causality which is based on the fact that cause cannot occur following an effect. The test can identify if X Granger cause Y and if so, it implies that the past information of X provides the opportunity to predict Y better than studying past information of Y for prediction when X is not used. Moreover, the test can analyze and measure the Granger causality between variables in time series by using empirical data sets in order to find patterns of correlation. Yet, ordinary Granger causality test cannot be used on nonstationary variables as it may lead to spurious regression and biased result. Thus, in case of non-stationary, one must transfer to the first or second difference of the data to transfer the variables to stationary for accurate results. Nonetheless, one can say that by taking the first or second difference of the variable, the long run relationship will be vanished, and the model only present the short-term GC relationship. Additionally, as taking the difference leads to lower power for the test, the risk of type 2 error will increase, and may question the trustworthiness of the result (Gujarati et al., 2012). However, Toda and Yamamoto and Dolado and Lütkepohl Granger causality test is not sensitive to stationary state and can be applied to all integration order series such as I(0) , I(1), and I(2) for both cointegrated and non-cointegrated time series (Granger, 1969; Ayad & BELMOKADDEM, 2017). Moreover, TYDL-GC consist of 4 steps, which the first one is to calculate maximum order of integration between the chosen variable, in which d_{max} is the highest order of integration. Second step is to calculate the optimal lag order, third is to determine the VAR model,

$$Y_{1t}=\beta_0+\beta_1 Y_{t-1}+\ldots.+\beta_k Y_{t-k}+\alpha_1 Y_{2t-1}+\ldots.+\alpha_k Y_{2t-k}+u_{1t}$$

$$Y_{2t}=\beta_0+\beta_1 Y_{2t-1}+\ldots.+\beta_k Y_{t-k}+\alpha_1 Y_{2t-1}+\ldots.+\alpha_k Y_{t-k}+u_{2t}$$

Where k is the number of lags.

And the fourth step is to conduct MWald test to analyze the Granger causal relationship between the variables. The result of the test can answer the question that whether some markets have a tendency to lead others, say gold and bitcoin in this case, and how do impulses transfer from gold market to bitcoin market. (Toda & Yamamoto, 1995).

4. Analysis and Results

In this section the reader will receive an insight in the analysis of the data and the primary results from the statistical tests.

4.1 Spearman's Rho Test Results

As changes in prices usually have more weight in comparison with returns, one must clarify the difference between correlation on price versus return. Since the correlation on prices are sensitive to the length of period, the prices have geometrically movements with trend and irregularity. Therefore, the prices are constantly trendy while they are moving upward/downward as a random walk. In the case of two time series data with zero trend, the upwards bias will be removed while the correlation between variables remains the same. This is due to the fact that correlation does not take trend into account since its only measures deviations from the mean return. Thus, to avoid bias, one must calculate the correlation coefficient on the asset's returns instead of prices (Alexander, 2008).

Spearman's Correlation	**Gold Return**	**Bitcoin Return**
Gold Return	1.000000	0.038280
Bitcoin Return	0.038280	1.000000

Table 2: Spearman's Rho on return

***Source**: Author's calculations*

Considering the facts mentioned above, one can say that Spearman's Rho outcome presented on Table 2, represents the results of the correlation between the gold and bitcoin returns. As the coefficient outcome is positive, one can say that both markets seem to be positively correlated. Nevertheless, the value of the coefficient is lying on 0.03828; however, since the p-value of 0.4329 is strongly insignificant at 5% significant level, one may conclude that the correlation is not statistically significant. Thus, with the result form this study as well as the study by Zhang & Mani (2021), which illustrates on the correlation between gold and bitcoin during COVID-19, one may say that this is reliable

evidence to accept the assumption that "there is no significant linear correlation between gold and bitcoin market" (Zhang & Mani, 2021).

4.2 Johansen's Cointegration & ADF Test Results

Variables	Null Hypothesis	P-Value	5% significant level	Results
Gold	Gold contains at least one unit root (non-stationary)	0.3060	Do not reject	Gold is non-stationary
Bitcoin	Bitcoin contains at least one unit root (non-stationary)	0.7803	Do not reject	Bitcoin is non-stationary

Table 3: Unit root test at level

***Source**: Author's calculations*

Variables	Null Hypothesis	P-Value	5% significant level	Results
Gold I(1)	Gold contains at least one unit root (non-stationary)	0.0000	Reject	Gold's 1st difference is stationary
Bitcoin I(1)	Bitcoin contains at least one unit root (non-stationary)	0.0000	Reject	Bitcoin's 1st difference is stationary

Table 4: Unit root test at 1st difference

***Source**: Author's calculations*

The Augmented Dickey-Fuller (ADF) unit root test has been conducted for the main time series which is the period between 2014 and 2022. As Table 3 above represents, with regards to the augmented Dickey-Fuller, it appears that both gold and bitcoin are considered as non-stationary time-series since both of their p-values are above a 5% significant level. Meaning that both variables follow a random walk with a trend. Nevertheless, as one can see in Table 4, both variables become stationary after taking first difference order over all the time horizons investigated, since both P-values are less than 5% significant level. This means that both bitcoin and gold are integrated on order one I(1). In general, ADF tests argues that one can empirically investigate the dynamics of bitcoin and gold prices to determine how these dynamics could affects investors' decisions during different form of financial uncertainty. In other words, the results of ADF test indicates the weak form of Efficient Market Hypothesis. However, although both gold and bitcoin follow a random walk, one should not take ADF test into consideration of absolute truth with respect to the market efficiency in the weak form; thus, future analysis is needed to acquire more reliable evidence since ADF test itself cannot satisfy the necessary conditions for weak form of EMH (Tokić et al., 2018; Campbell et al., 1997). Since ADF test determined non-stationarity of variables, Johansen's cointegration test can be conducted to determine whether there is a long-run relationship between the variables.

Variable	**Series**	**Test**	**Hypothesized No. of CE (s)**	**Trace statistic/Max-Eigen Statistic**	**0.05 critical value**	**Prob. ****	**Cointegration**
Gold	**Bitcoin**	Trace test	None	0.038563	25.87211	0.1845	No
			At most 1	0.011175	12.51789	0.6484	
		Maximum Eigenvalue	None	0.038563	19.38704	0.1352	No
			At most 1	0.011175	12.51798	0.6484	

Table 5: Johansen's cointegration test

***Source**: Author's calculations*

After analyzing the stationarity of the variables, one must run the cointegration test to see whether the variables are correlated in the long term or not. In order to proceed with cointegration estimation, the symmetric cointegration test was conducted to analyze the long-term relationship between the variables. The null hypothesis of Johansen's cointegration test states that no cointegration between variables exists and the alternative hypothesis says otherwise. The outcome of the tests for cointegration can be found in Table 5. The t-statistics of both the Trace test and the Maximum Eigenvalue suggests that bitcoin and gold prices are not cointegrated at a 5% significant level. Thus, the results suggest that the non-existence long-term relationship or cointegration among bitcoin and gold prices. The results infer that the relationship between gold and bitcoin could be weak. One can seek to substantiate this view by comparing this result with the results from Spearman's Rho correlation, which indicates the same conclusion. Granger (1986) points out that one of the conditions for the efficient market is that there should be no cointegration relationship between assets prices since the existence of cointegration could lead to use historical price of one variable to predict other ones (Granger, 1986; TAŞ & TOKMAKÇIOĞLU, 2010). However, a study by Sweeney (2003) argues that cointegration or lack of cointegration within variables does not indicate market efficiency by itself. Thus, one cannot draw a conclusion that gold and bitcoin are efficient in semi strong form based on cointegration test results (Sweeney, 2003). However, as the results are not conclusive, TYDL-GC test will proceed to further verify and confirm the existence of any relationship between gold and bitcoin markets.

4.3 Toda & Yamamoto and Dolado & Lütkepohl Granger Causality (TYDL-GC) Test Results

Time period	Null hypothesis(H0)	Prob.	Choice (5% significant level)	Results	Direction of Causality
Entire sample	Gold does not Granger cause Bitcoin	0.0003	Reject H0	Gold does Granger cause Bitcoin	Gold → Bitcoin
	Bitcoin does not Granger cause Gold	0.0685	Accept H0	Bitcoin does not Granger cause Gold	
Financial crisis 2015-2016	Gold does not Granger cause Bitcoin	0.0432	Reject H0	Gold does Granger cause Bitcoin	Gold → Bitcoin
	Bitcoin does not Granger cause Gold	0.5837	Accept H0	Bitcoin does not Granger cause Gold	
COVID-19 2020-2022	Gold does not Granger cause Bitcoin	0.9621	Accept H0	Gold does not Granger cause Bitcoin	**No Granger Causality**
	Bitcoin does not Granger cause Gold	0.5291	Accept H0	Bitcoin does not Granger cause Gold	

Table 6: TYDL-GC test

***Source**: Author's calculations*

4.3.1 Short-term and Long-term Causality Link

This study has examined both short-term and long-term Granger causality link between gold and bitcoin prices by using their historical spot prices. To begin with, the entire sample has been analyzed to examine the long-term relationship followed by other financial crisis periods during the datasets for the sake of clarification on the short-term effects.

4.3.2 Whole Sample

In the entire sample, the Granger causality link has been found from gold prices towards bitcoin prices but not vice versa (Table 6). This result indicates the existence of long-term Granger causality from gold towards the bitcoin market. The results from this study can be backed up with the claim of Bhuiyan et al. (2021) and Upadhyay et al. (2018), who found the strong Granger causality link from gold prices towards bitcoin (Bhuiyan et al., 2021; Upadhyay et al., 2018). The authors did not clarify whether they found causality within long- or short-terms, alternatively, this study suggests that the causality link exist only in the long-terms and not in the short-terms, meaning that all price fluctuations in the gold market do not necessary influence bitcoin market in the short-term. Furthermore, by examining the results of the different financial events, this study therefore seeks to confirm whether the Granger causality link between the variables is consistent. Knowing the consistency of Granger causality correlation can be beneficial for investors to know how stable this relationship is overtime, since based on Granger causality hypothesis, gold's historical price could be useful for forecasting the bitcoin market. As it was discussed previously, the semi strong Efficient Market hypothesis requires no Granger causality relationship between the variables. However, as the results of TYDL-GC test determined existence of Granger causality from gold towards bitcoin, one can say that the bitcoin market is not efficient in a semi strong form since the results violates the main condition of the EMH theory (Brunetti et al., 2011; Grosche, 2014).

4.3.3 The 2015 Financial Crisis

During the financial crisis of 2015, the causality link was found once again from gold prices towards bitcoin prices but not vice versa. As the examined period is more than 2 years, one can say that it is neither a short- nor long-term duration, but med-term. These results can be backs up by the finding of Gkillas et al. (2020) which argues that gold is a transmitter during financial events and bitcoin is a receiver of gold price changes (Gkillas et al., 2020). Thus, one can further note that bitcoin prices are dependent on gold markets in long- and med-term periods. Which could develop the assumption that these effects indicates that past gold prices could curb future bitcoin prices over the long- and med-

term periods. Nonetheless, this assumption violates the efficient market assumption and yet it contrasts with the random walk theory (Fama, 1970).

4.3.4 The COVID-19 Crisis

During the COVID-19 pandemic, no Granger causality link was found between the gold and bitcoin markets. The result from the COVID-19 pandemic period infers that gold prices weakened or failed to determine bitcoin prices during the pandemic. Unlike the 2 previous periods, as no relationship has been determined between variables, one may say that the Granger causality link disappears in the short terms. These findings can be supported by the study of Dončić (2020), which claimed that the historical price movements of gold cannot be used to predict the bitcoin market for a 1-year period in 2019 (Dončić, 2020). Nevertheless, by testing the result over another event, one could attempt to confirm whether the COVID-19 pandemic is the exclusive cause from the entire scenario, or if the Granger causality link is sensitive to the duration length of this study.

5. Conclusion and Discussion

This chapter introduces the conclusion of the findings of this study by answering the research question. Additionally, potential areas for future research have been explained thereafter.

The analysis of this paper includes gold and bitcoin data from the 8-year time period between 2014 and 2022 in different unusual financial and economic events such as the 2015 financial crisis, and the COVID-19 pandemic. This pattern increases the possibility of using data within different time spans and comparing them to the larger data span. Three tests have been applied on the data to determine the true relationship between the variables and get reliable results from the outcomes. The findings from Spearman's Rho implies that bitcoin and gold returns are positively correlated. Meaning that in case of market turmoil which gold prices is bearish, investors cannot take refuge in bitcoin as a hedge, since it may cause the price of bitcoin to decrease as well. Nonetheless, as Johansen's cointegration tests indicates no long-term relationship between gold and bitcoin, one can argue that the correlation between the variables does not exist in the long-term. During the entire test sample and financial crisis in 2015, the empirical results has shown Granger causality link from gold prices towards bitcoin prices but not vice versa. Meaning that using time-varying Toda & Yamamoto and Dolado & Lütkepohl Granger causality tests, identified the unilateral effects of price changes from gold to bitcoin markets during the 8-year period. However, the causality link has disappeared in the next period which contains the COVID-19 pandemic. Additionally, as there is no link between assets in short-terms, investors can use both assets in their portfolio for the sake of diversification and higher returns in the short-terms. Although a semi strong form of EMH has been supported by the results from cointegration tests, TYDL Granger causality tests has indicated a relationship between gold and bitcoin, which is not in accordance with the semi strong EMH form. This research found that using gold behavior data to forecast the bitcoin prices during long-term sample data is feasible. The results suggest the necessity of testing at a large range of data when forecasting gold and bitcoin time series, even if the variables are heterogeneous in short terms. Prominently, both bitcoin and gold tend to come into investor's focus during unexpected financial events. Yet, both assets are volatile based on the trend and unsystematic information in the market in the short-term.

Which could be the reason for weakening Granger causality link between gold and bitcoin in the short-term. The empirical results from different time periods offer relatively stable and consistent evidence that, both bitcoin and gold are sensitive to market news and unsystematic information and can lead the price movement of both assets in the short run. Thus, one may say that these short-term effects can be the reason why the Granger causality link disappears between bitcoin and gold in the short terms. However, bitcoin seems to be susceptible to price changes and fluctuations in the gold market in long-terms. Moreover, the findings from this study suggests that gold prices are an important leading factor for the bitcoin market and investors can predict bitcoin price movements by using gold's historical prices for long-term forecasting. From the results of this study, one can say that the most reasonable intercept is that the Granger causality relationship between both assets exists only in the long-term, but not short terms. Meaning that the Granger causality from gold prices towards bitcoin prices is not stable during different financial events, and it may disappear from time to time. Thus, the study found evidence that although there is Granger causality link between the assets in the long-term, both assets follow a random walk and do not Granger cause each other in short terms. Although gold prices impacted the bitcoin market in the long-term, the gold price relation towards bitcoin market has weakened in the short-term. The reason for the existence of Granger causality between bitcoin and gold could be due to the reason that when gold price increases, investors take bitcoin into their portfolio with the assumption that increases in the gold value can cause increases in the bitcoin value, which may cause rises in the bitcoin prices.

Future research within this topic could be to extend the testing by include GARCH model in order to study the volatility of both assets during the mentioned financial crises and a longer time span. Additionally, a prediction model can be made to predict bitcoin's future prices by using gold historical prices. Furthermore, a quantify association between the data span during the current Ukraine war is called for, especially after market stabilization post war. Although there are many studies on bitcoin as a new payment system or new phenomenon in the economy, there are not many written articles about the effect of bitcoin on the economy nor causes from or towards bitcoin within financial markets. As cryptocurrencies are becoming more and more important in the economies, deep studies on their behavior and correlation with other assets could be beneficial to study.

Reference list

Aggarwal, D. (2019). Do bitcoins follow a random walk model? *Research in Economics*, *73*(1), 15–22. https://doi.org/10.1016/j.rie.2019.01.002

Agyei-Ampomah, S., Gounopoulos, D., & Mazouz, K. (2014). Does gold offer a better protection against losses in sovereign debt bonds than other metals? *Journal of Banking & Finance*, *40*, 507–521. https://doi.org/10.1016/j.jbankfin.2013.11.014

Alexander, C. (2008). *Market models : a guide to financial data analysis*. Wiley.

Alfieri, E., Burlacu, R., & Enjolras, G. (2019). On the nature and financial performance of bitcoin. *The Journal of Risk Finance*, *20*(2), 114–137. https://doi.org/10.1108/jrf-03-2018-0035

Atri, H., Kouki, S., & Gallali, M. imen. (2021). The impact of COVID-19 news, panic and media coverage on the oil and gold prices: An ARDL approach. *Resources Policy*, *72*, 102061. https://doi.org/10.1016/j.resourpol.2021.102061

Ayad, H., & BELMOKADDEM, M. (2017). Financial development, trade openness and economic growth in MENA countries: TYDL panel causality approach. *Theoretical and Applied Economics*, *XXIV*(1), 233–246. http://store.ectap.ro/articole/1259.pdf

Barro, R. J., & Misra, S. (2016). Gold Returns. *The Economic Journal*, *126*(594), 1293–1317. https://doi.org/10.1111/ecoj.12274

Baur, D. G., Dimpfl, T., & Kuck, K. (2018). Bitcoin, gold and the US dollar – A replication and extension. *Finance Research Letters*, *25*, 103–110. https://doi.org/10.1016/j.frl.2017.10.012

Baur, D. G., & Hoang, L. (2021). The Bitcoin gold correlation puzzle. *Journal of Behavioral and Experimental Finance*, *32*, 100561. https://doi.org/10.1016/j.jbef.2021.100561

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. https://doi.org/10.1111/j.1540-6288.2010.00244.x

Baur, D. G., & McDermott, T. K. J. (2009). Is Gold a Safe Haven? International Evidence. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.1516838

Beck, N. (1992). The Methodology of Cointegration. *Political Analysis*, *4*, 237–247. https://doi.org/10.1093/pan/4.1.237

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. https://doi.org/10.1016/j.econmod.2014.10.044

Beckmann, J., & Czudaj, R. (2013). Gold as an inflation hedge in a time-varying coefficient framework. *The North American Journal of Economics and Finance*, *24*, 208–222. https://doi.org/10.1016/j.najef.2012.10.007

Bhuiyan, R. A., Husain, A., & Zhang, C. (2021). A wavelet approach for causal relationship between bitcoin and conventional asset classes. *Resources Policy*, *71*, 101971. https://doi.org/10.1016/j.resourpol.2020.101971

Böhme, R., Christin, N., Edelman, B., & Moore, T. (2015). Bitcoin: Economics, Technology, and Governance. *Journal of Economic Perspectives*, *29*(2), 213–238. https://doi.org/10.1257/jep.29.2.213

Bordo, M., Monnet, E., & Naef, A. (2019). The Gold Pool (1961–1968) and the Fall of the Bretton Woods System: Lessons for Central Bank Cooperation. *The Journal*

of Economic History, *79*(4), 1027–1059. Retrieved from: https://doi.org/10.1017/s0022050719000548

Bouri, E., Molnár, P., Azzi, G., Roubaud, D., & Hagfors, L. I. (2017). On the hedge and safe haven properties of Bitcoin: Is it really more than a diversifier? *Finance Research Letters*, *20*, 192–198. https://doi.org/10.1016/j.frl.2016.09.025

Brophy, R. (2019). Blockchain and insurance: a review for operations and regulation. *Journal of Financial Regulation and Compliance*, *ahead-of-print*(ahead-of-print). https://doi.org/10.1108/jfrc-09-2018-0127

Brunetti, C., Buyuksahin, B., & Harris, J. H. (2011). Speculators, Prices and Market Volatility. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.1736737

Brunnermeier, M. K., James, H., & Landau, J.-P. (2019, September 19). *The Digitalization of Money*. National Bureau of Economic Research Working Paper Series. https://www.nber.org/papers/w26300

Campbell, J. Y., Lo, A. W., & Archie Craig Mackinlay. (1997). *The econometrics of financial markets*. Princeton University Press.

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. https://doi.org/10.1016/j.intfin.2004.07.002

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. https://doi.org/10.1016/j.econlet.2015.02.029

Dickey, D. A., & Fuller, W. A. (1979). Distribution of the Estimators for Autoregressive Time Series With a Unit Root. *Journal of the American Statistical Association*, *74*(366), 427. https://doi.org/10.2307/2286348

Dimitriou, D., Kenourgios, D., & Simos, T. (2020). Are there any other safe haven assets? Evidence for “exotic” and alternative assets. *International Review of Economics & Finance*, *69*, 614–628. https://doi.org/10.1016/j.iref.2020.07.002

Dončić, S. (2020). Testing the causality between Bitcoin price and the gold price in the global market prime by Granger’s test. *Ekonomika*, *66*(3), 73–80. https://doi.org/10.5937/ekonomika2003073d

Doumenis, Y., Izadi, J., Dhamdhere, P., Katsikas, E., & Koufopoulos, D. (2021). A Critical Analysis of Volatility Surprise in Bitcoin Cryptocurrency and Other Financial Assets. *Risks*, *9*(11), 207. https://doi.org/10.3390/risks9110207

Durusu-Ciftci, D., Ispir, M. S., & Kok, D. (2019). Do stock markets follow a random walk? New evidence for an old question. *International Review of Economics & Finance*, *64*, 165–175. https://doi.org/10.1016/j.iref.2019.06.002

Dyhrberg, A. H. (2016). Bitcoin, gold and the dollar – A GARCH volatility analysis. *Finance Research Letters*, *16*, 85–92. https://doi.org/10.1016/j.frl.2015.10.008

Everett, C. (2018). *The Cryptocurrency Investing Guide: How to Invest and Trade Cryptocurrencies for BIG Profit.* R&C Publishing. https://bookshout.com/ebooks/the-cryptocurrency-investing-guide

FAMA, E. F. (1991). Efficient Capital Markets: II. *The Journal of Finance*, *46*(5), 1575–1617. https://doi.org/10.1111/j.1540-6261.1991.tb04636.x

Fama, E. F. (1970). Efficient Capital Markets: a Review of Theory and Empirical Work. *The Journal of Finance*, *25*(2), 383–417. https://doi.org/10.2307/2325486

Franzotti, T., & Valle, M. (2020). The impact of crises on investments and financing of Brazilian companies: an approach in the context of financial constraints. *Brazilian Business Review*, *17*(2), 233–252. https://doi.org/10.15728/bbr.2020.17.2.6

Gkillas, K., Bouri, E., Gupta, R., & Roubaud, D. (2020). Spillovers in Higher-Order Moments of Crude Oil, Gold, and Bitcoin. *The Quarterly Review of Economics and Finance*. https://doi.org/10.1016/j.qref.2020.08.004

Glaser, F., Zimmermann, K., Haferkorn, M., Weber, M. C., & Siering, M. (2014, April 15). *Bitcoin - Asset or Currency? Revealing Users' Hidden Intentions*. Papers.ssrn.com. http://ssrn.com/abstract=2425247

Gopal, S., & Munusamy, J. (2016). Causal Relationship between Gold, Crude Oil & US Dollar Rates and S&P BSE 100 in India: An Experimental Study. *International Journal of Financial Management*, *6*(2). https://doi.org/10.21863/ijfm/2016.6.2.031

Granger, C. W. J. (1969). Investigating Causal Relations by Econometric Models and Cross-spectral Methods. *Econometrica*, *37*(3), 424. https://doi.org/10.2307/1912791

Granger, C. W. J. (1986). DEVELOPMENTS IN THE STUDY OF COINTEGRATED ECONOMIC VARIABLES. *Oxford Bulletin of Economics and Statistics*, *48*(3), 213–228. https://doi.org/10.1111/j.1468-0084.1986.mp48003002.x

Grobys, K. (2020). When Bitcoin Has the Flu: On Bitcoin's Performance to Hedge Equity Risk in the Early Wake of the COVID-19 Outbreak. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3565844

Grosche, S.-C. (2014). What Does Granger Causality Prove? A Critical Examination of the Interpretation of Granger Causality Results on Price Effects of Index Trading in Agricultural Commodity Markets. *Journal of Agricultural Economics*, *65*(2), 279–302. https://doi.org/10.1111/1477-9552.12058

Guan, L., Zhang, W.-W., Ahmad, F., & Naqvi, B. (2021). The volatility of natural resource prices and its impact on the economic growth for natural resource-

dependent economies: A comparison of oil and gold dependent economies. *Resources Policy*, *72*, 102125. https://doi.org/10.1016/j.resourpol.2021.102125

Guesmi, K., Saadi, S., Abid, I., & Ftiti, Z. (2018). Portfolio diversification with virtual currency: Evidence from bitcoin. *International Review of Financial Analysis*. https://doi.org/10.1016/j.irfa.2018.03.004

Gujarati, D. N., Porter, D. C., & Sangeetha Gunasekar. (2012). *Basic econometrics*. Mcgraw-Hill Education (India) Private Limited.

Hajek, P., & Novotny, J. (2022). Fuzzy Rule-Based Prediction of Gold Prices using News Affect. *Expert Systems with Applications*, *193*, 116487. https://doi.org/10.1016/j.eswa.2021.116487

Harris, R. D. F., & Shen, J. (2017). The intrinsic value of gold: An exchange rate-free price index. *Journal of International Money and Finance*, *79*, 203–217. https://doi.org/10.1016/j.jimonfin.2017.09.007

Huberman, G., Leshno, J., & Moallemi, C. C. (2017). Monopoly Without a Monopolist: An Economic Analysis of the Bitcoin Payment System. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3032375

Hung, N. T. (2022). Asymmetric connectedness among S&P 500, crude oil, gold and Bitcoin. *Managerial Finance*, *48*(4), 587–610. https://doi.org/10.1108/mf-08-2021-0355

Huynh, T. L. D. (2022). When Elon Musk Changes his Tone, Does Bitcoin Adjust Its Tune? *Computational Economics*. https://doi.org/10.1007/s10614-021-10230-6

Jareño, F., González, M. de la O., Tolentino, M., & Sierra, K. (2020). Bitcoin and gold price returns: A quantile regression and NARDL analysis. *Resources Policy*, *67*, 101666. https://doi.org/10.1016/j.resourpol.2020.101666

Jensen, M. C. (1978). Some anomalous evidence regarding market efficiency. *Journal of Financial Economics*, *6*(2-3), 95–101. https://doi.org/10.1016/0304-405x(78)90025-9

Ji, Q., Zhang, D., & Zhao, Y. (2020). Searching for Safe-haven Assets During the COVID-19 Pandemic. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3602780

Johansen, S. (1988). Statistical analysis of cointegration vectors. *Journal of Economic Dynamics and Control*, *12*(2-3), 231–254. https://doi.org/10.1016/0165-1889(88)90041-3

Joy, M. (2011). Gold and the US dollar: Hedge or haven? *Finance Research Letters*, *8*(3), 120–131. https://doi.org/10.1016/j.frl.2011.01.001

Kitamura, Y. (1998). LIKELIHOOD-BASED INFERENCE IN COINTEGRATED VECTOR AUTOREGRESSIVE MODELS. *Econometric Theory*, *14*(4), 517–524. https://doi.org/10.1017/s0266466698144067

Klein, T., Pham Thu, H., & 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. https://doi.org/10.1016/j.irfa.2018.07.010

Laboure, M., & Reid, J. (2020, January). *Download Pdf*. Www.dbresearch.com. https://www.dbresearch.com/PROD/RPS_EN-PROD/PROD0000000000504589/The_Future_of_Payments_-_Part_III__Digital_Currenc.pdf?undefined&realload=~3dDXaroXw8bxXN5kfwh2pkWvo0aWUOG4B08aFqIY1JeypAZL8QTM~8nycqNZ~R0

Larsson, R. (1997). Book Review: Johansen, Søren: Likelihood-based Inference in Cointegrated Vector Autoregressive Models Clarendon Press, Oxford, 1995,

x+267 pp. ISBN 0-19-877449-4. *The Scandinavian Journal of Economics*, *99*(2), 351–354. https://doi.org/10.1111/1467-9442.00067

LeBaron, B. (1999). Technical trading rule profitability and foreign exchange intervention. *Journal of International Economics*, *49*(1), 125–143. https://doi.org/10.1016/s0022-1996(98)00061-0

Litwack, S. (2015). *BITCOIN: CURRENCY OR FOOL'S GOLD?: A COMPARATIVE ANALYSIS OF THE LEGAL CLASSIFICATION OF BITCOIN*. https://sites.temple.edu/ticlj/files/2017/02/29.2.Litwack-TICLJ.pdf

Lo, A. W., Mamaysky, H., & Wang, J. (2000). Foundations of Technical Analysis: Computational Algorithms, Statistical Inference, and Empirical Implementation. *The Journal of Finance*, *55*(4), 1705–1765. https://doi.org/10.1111/0022-1082.00265

Luo, X. (2009). Quantifying the Long-Term Impact of Negative Word of Mouth on Cash Flows and Stock Prices. *Marketing Science*, *28*(1), 148–165. https://doi.org/10.1287/mksc.1080.0389

Mahase, E. (2020). Covid-19: WHO declares pandemic because of "alarming levels" of spread, severity, and inaction. *BMJ*, *368*, m1036. https://doi.org/10.1136/bmj.m1036

Marella, V., Upreti, B., Merikivi, J., & Tuunainen, V. K. (2020). Understanding the creation of trust in cryptocurrencies: the case of Bitcoin. *Electronic Markets*. https://doi.org/10.1007/s12525-019-00392-5

Matei, I.-G., & Baks, E. W. (2019). Regulating Bitcoin – The Challenges Ahead. *Acta Universitatis Danubius*, *15*(3).

Matkovskyy, R., & Jalan, A. (2020). Bitcoin vs Inflation: Can Bitcoin Be a Macro Hedge? Evidence From a Quantile-on-Quantile Model. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3750619

McGregor, P., Carse, S., Williamson, J., & Wood, G. (1981). The Financing Procedures of British Foreign Trade. *The Economic Journal*, *91*(362), 571. https://doi.org/10.2307/2232621

Merkaš, Z., & Roška, V. (2021). The Impact of Unsystematic Factors on Bitcoin Value. *Journal of Risk and Financial Management*, *14*(11), 546. https://doi.org/10.3390/jrfm14110546

Ozturk, S. S. (2020). Dynamic Connectedness between Bitcoin, Gold, and Crude Oil Volatilities and Returns. *Journal of Risk and Financial Management*, *13*(11), 275. https://doi.org/10.3390/jrfm13110275

Paparoditis, E., & Politis, D. N. (2016). The asymptotic size and power of the augmented Dickey–Fuller test for a unit root. *Econometric Reviews*, *37*(9), 955–973. https://doi.org/10.1080/00927872.2016.1178887

Pho, K. H., Ly, S., Lu, R., Hoang, T. H. V., & Wong, W.-K. (2021). Is Bitcoin a better portfolio diversifier than gold? A copula and sectoral analysis for China. *International Review of Financial Analysis*, *74*, 101674. https://doi.org/10.1016/j.irfa.2021.101674

Piñeiro-Chousa, J., López-Cabarcos, M. Á., Pérez-Pico, A. M., & Ribeiro-Navarrete, B. (2018). Does social network sentiment influence the relationship between the S&P 500 and gold returns? *International Review of Financial Analysis*, *57*, 57–64. https://doi.org/10.1016/j.irfa.2018.02.005

Prion, S., & Haerling, K. A. (2014). Making Sense of Methods and Measurement: Spearman-Rho Ranked-Order Correlation Coefficient. *Clinical Simulation in Nursing*, *10*(10), 535–536. https://doi.org/10.1016/j.ecns.2014.07.005

Puth, M.-T., Neuhäuser, M., & Ruxton, G. D. (2015). Effective use of Spearman's and Kendall's correlation coefficients for association between two measured traits. *Animal Behaviour*, *102*, 77–84. https://doi.org/10.1016/j.anbehav.2015.01.010

Sabalionis, A., Wang, W., & Park, H. (2020). What affects the price movements in Bitcoin and Ethereum? *The Manchester School*. https://doi.org/10.1111/manc.12352

Sarkodie, S. A., Ahmed, M. Y., & Owusu, P. A. (2021). COVID-19 pandemic improves market signals of cryptocurrencies–evidence from Bitcoin, Bitcoin Cash, Ethereum, and Litecoin. *Finance Research Letters*, 102049. https://doi.org/10.1016/j.frl.2021.102049

Shahbaz, M., Balcilar, M., & Abidin Ozdemir, Z. (2017). Does oil predict gold? A nonparametric causality-in-quantiles approach. *Resources Policy*, *52*, 257–265. https://doi.org/10.1016/j.resourpol.2017.03.004

Shukor, S. A., Sufahani, S. F., Khalid, K., Wahab, M. H. A., Idrus, S. Z. S., Ahmad, A., & Subramaniam, T. S. (2021). Forecasting Stock Market Price of Gold, Silver, Crude Oil and Platinum by Using Double Exponential Smoothing, Holt's Linear Trend and Random Walk. *Journal of Physics: Conference Series*, *1874*(1), 012087. https://doi.org/10.1088/1742-6596/1874/1/012087

Slater, A. (2022). Rising quit rates are a possible inflation signal. *Economic Outlook*, *46*(1), 24–27. https://doi.org/10.1111/1468-0319.12601

Spiro, N. (2022). Ukraine invasion is a "Lehman moment" for global economy: Investors were caught off guard by Russia's escalation of the conflict and the West's resolve to punish Moscow with severe sanctions. *South China Morning Post*.

Su, C.-W., Qin, M., Tao, R., & Zhang, X. (2020). Is the status of gold threatened by Bitcoin? *Economic Research-Ekonomska Istraživanja*, *33*(1), 420–437. https://doi.org/10.1080/1331677x.2020.1718524

Sweeney, R. J. (2003). Cointegration and Market Efficiency. *Journal of Emerging Market Finance*, *2*(1), 41–56. https://doi.org/10.1177/097265270300200102

Tam, P. S. (2012). Finite-sample distribution of the augmented Dickey–Fuller test with lag optimization. *Applied Economics*, *45*(24), 16. https://doi.org/https://doi-org.proxy.library.ju.se/10.1080/00036846.2012.724159

TAŞ, O., & TOKMAKÇIOĞLU, K. (2010). Efficient Market Hypothesis and Comovement Among Emerging Markets. *Doğuş Üniversitesi Dergisi*, *2*(11), 286–301. https://doi.org/10.31671/dogus.2019.169

Toda, H. Y., & Yamamoto, T. (1995). Statistical inference in vector autoregressions with possibly integrated processes. *Journal of Econometrics*, *66*(1-2), 225–250. https://doi.org/10.1016/0304-4076(94)01616-8

Tokić, S., Bolfek, B., & Radman Peša, A. (2018). Testing efficient market hypothesis in developing Eastern European countries. *Investment Management and Financial Innovations*, *15*(2), 281–291. https://doi.org/10.21511/imfi.15(2).2018.25

Troster, V., Tiwari, A. K., Shahbaz, M., & Macedo, D. N. (2019). Bitcoin returns and risk: A general GARCH and GAS analysis. *Finance Research Letters*, *30*, 187–193. https://doi.org/10.1016/j.frl.2018.09.014

Upadhyay, H. J., Raichura, B., & Shah, R. (2018). Interrelation of BITCOIN with Euro, Gold, Nifty, Crude oil and Ripple: A Causality Test. *Journal of Management & Research*, *8*(2).

Urquhart, A., & Zhang, H. (2018). Is Bitcoin a Hedge or Safe-Haven for Currencies? An Intraday Analysis. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3114108

Wang, X., & Hui, X. (2018). Cross-Sectoral Information Transfer in the Chinese Stock Market around Its Crash in 2015. *Entropy*, *20*(9), 663. https://doi.org/10.3390/e20090663

World Gold Council. (n.d.). *World Gold Council | The Authority on Gold*. World Gold Council. https://www.gold.org

Yahoo Finance. (n.d.). *All Cryptocurrencies Screener - Yahoo Finance*. Finance.yahoo.com. Retrieved April 4, 2022, from https://finance.yahoo.com/cryptocurrencies/

Yancey, G. B., & Krome, L. R. (2021). Organizational responses in 2020: Addressing COVID-19, the economic recession, and the black lives matter movement. *The Psychologist-Manager Journal*, *24*(4), 250–273. https://doi.org/10.1037/mgr0000120

Zhang, S., & Mani, G. (2021). Popular cryptoassets (Bitcoin, Ethereum, and Dogecoin), Gold, and their relationships: Volatility and correlation modeling. *Data Science and Management*, *4*, 30–39. https://doi.org/10.1016/j.dsm.2021.11.001

Zhang, Y.-J., & Wei, Y.-M. (2010). The crude oil market and the gold market: Evidence for cointegration, causality and price discovery. *Resources Policy*, *35*(3), 168–177. https://doi.org/10.1016/j.resourpol.2010.05.003

Zhu, Z. (1998). The random walk of stock prices: evidence from a panel of G-7 countries. *Applied Economics Letters*, *5*(7), 411–413. https://doi.org/10.1080/135048598354528

Zvi Bodie, Kane, A., & Marcus, A. J. (2021). *Investments*. New York, Ny Mcgraw-Hill.

Østbye, P. (2018). The Case for a 21 Million Bitcoin Conspiracy. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3136044

Appendices

Appendix 1 Normality Test

VAR Residual Normality Tests
Orthogonalization: Cholesky (Lutkepohl)
Null Hypothesis: Residuals are multivariate normal
Date: 04/07/22 Time: 11:35
Sample: 11/24/2013 12/26/2021
Included observations: 421

Component	Skewness	Chi-sq	df	Prob.*
1	-0.160649	1.810878	1	0.1784
2	-0.008909	0.005569	1	0.9405
Joint		1.816447	2	0.4032

Component	Kurtosis	Chi-sq	df	Prob.
1	11.70356	1328.814	1	0.0000
2	16.17810	3046.329	1	0.0000
Joint		4375.143	2	0.0000

Component	Jarque-Bera	df	Prob.
1	1330.625	2	0.0000
2	3046.334	2	0.0000
Joint	4376.959	4	0.0000

Appendix 2 ADF Stationary Test

Null Hypothesis: GOLD has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=17)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.545560	0.3060
Test critical values:	1% level	-3.979954	
	5% level	-3.420507	
	10% level	-3.132944	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: BITCOIN has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 3 (Automatic - based on SIC, maxlag=17)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.628453	0.7803
Test critical values:	1% level	-3.980112	
	5% level	-3.420584	
	10% level	-3.132989	

*MacKinnon (1996) one-sided p-values.

Appendix 3 First Order Difference

Null Hypothesis: D(GOLD) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=17)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-20.16203	0.0000
Test critical values:	1% level	-3.445664	
	5% level	-2.868186	
	10% level	-2.570375	

*MacKinnon (1996) one-sided p-values.
Null Hypothesis: D(BITCOIN) has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=17)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-15.99873	0.0000
Test critical values:	1% level	-3.445701	
	5% level	-2.868202	
	10% level	-2.570384	

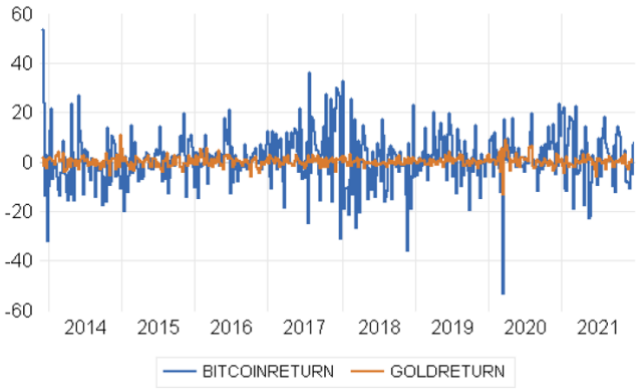
*MacKinnon (1996) one-sided p-values.

Appendix 4 Spearman's Rho Test

Covariance Analysis: Spearman rank-order
Date: 04/08/22 Time: 20:49
Sample: 12/01/2013 12/26/2021
Included observations: 422
Balanced sample (listwise missing value deletion)

Correlation	GOLDRETU...	BITCOINRE...
GOLDRETURN	1.000000	
BITCOINRETURN	0.038280	1.000000

Probability	GOLDRETU...	BITCOINRE...
GOLDRETURN	-----	
BITCOINRETURN	0.4329	-----



Appendix 5 Johansen's Cointegration Test

Date: 04/07/22 Time: 11:25
Sample (adjusted): 2/02/2014 12/26/2021
Included observations: 413 after adjustments
Trend assumption: Linear deterministic trend (restricted)
Series: GOLD BITCOIN
Lags interval (in first differences): 1 to 9

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None	0.038563	20.88264	25.87211	0.1845
At most 1	0.011175	4.641088	12.51798	0.6484

Trace test indicates no cointegration at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None	0.038563	16.24156	19.38704	0.1352
At most 1	0.011175	4.641088	12.51798	0.6484

Max-eigenvalue test indicates no cointegration at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Appendix 6 Toda & Yamamoto and Dolado & Lütkepohl Granger Causality Test (TYDL-GC)

VAR Granger Causality/Block Exogeneity Wald Tests
Date: 04/07/22 Time: 11:30
Sample: 11/24/2013 12/26/2021
Included observations: 414

Dependent variable: GOLD

Excluded	Chi-sq	df	Prob.
BITCOIN	15.92244	9	0.0685
All	15.92244	9	0.0685

Dependent variable: BITCOIN

Excluded	Chi-sq	df	Prob.
GOLD	30.79977	9	0.0003
All	30.79977	9	0.0003

VAR Granger Causality/Block Exogeneity Wald Tests
Date: 04/08/22 Time: 20:28
Sample: 1/26/2020 12/26/2021
Included observations: 101

Dependent variable: BITCOIN

Excluded	Chi-sq	df	Prob.
GOLD	0.002261	1	0.9621
All	0.002261	1	0.9621

Dependent variable: GOLD

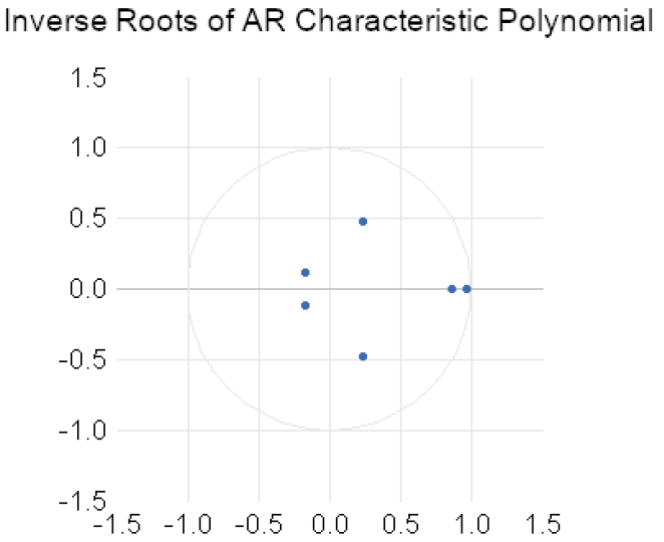
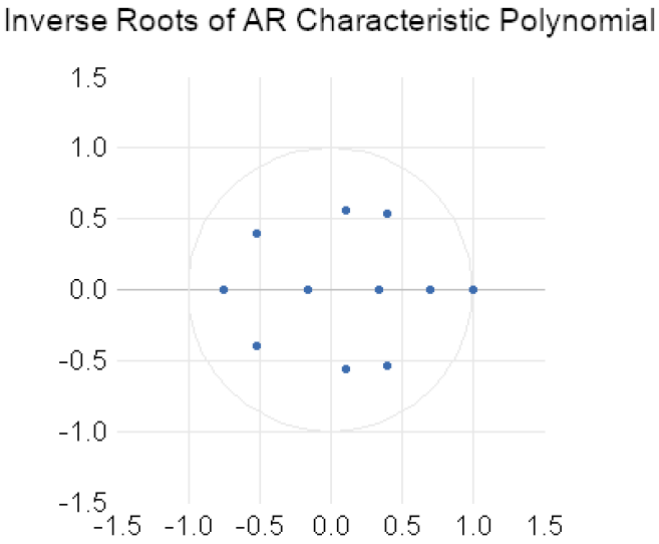
Excluded	Chi-sq	df	Prob.
BITCOIN	0.396209	1	0.5291
All	0.396209	1	0.5291

VAR Granger Causality/Block Exogeneity Wald Tests
Date: 04/08/22 Time: 21:41
Sample: 1/04/2015 12/25/2016
Included observations: 104

Dependent variable: GOLD

Excluded	Chi-sq	df	Prob.
BITCOIN	1.076830	2	0.5837
All	1.076830	2	0.5837

Dependent variable: BITCOIN

Excluded	Chi-sq	df	Prob.
GOLD	6.284765	2	0.0432
All	6.284765	2	0.0432

Appendix 7 Inverse Roots