Is Bitcoin an Inflation-Hedge?

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Abstract

The recent monetary stimulus and economic uncertainty that has followed since the onset of COVID-19 has had investors considering their options in terms of hedging against inflation. Bitcoin (BTC), which is being labelled the 'digital gold' has emerged since the last financial crisis (Great Recession 2007-2009) where we last observed high levels of sustained inflation and has given investors something to consider in terms of the assets used to hedge against inflation. By critically evaluating literature, I have established other scholars views in support of BTC's inflation-hedging properties as well as other scholars who question the validity and propose other more 'traditional' assets as more suitable hedges against inflation, such as gold and stocks. My findings from the literature review led me to comparing my data analysis and statistical modelling of BTC's inflation hedging-properties against spot gold prices and the Nasdaq 100 stock index, which function as a benchmark. By using Dynamic Conditional Correlation GARCH (GARCH) I was able to determine that BTC prices are far more volatile than both my benchmark assets, which means there is a higher level of financial risk associated with BTC and leads me to question the inflation-hedging effectiveness of BTC. Spot gold price returns have a significantly stronger time-varying volatility correlation with inflation (CPI) than BTC which is a strong indication that BTC inflation-hedging properties are not as prevalent as those of gold. I have not relied solely on DCC-GARCH analysis to determine if BTC is an inflation-hedge, I have gone a step further to answer the research question by also estimating Vector Autoregressive Models (VAR), which provides evidence on the relationship between BTC and inflation, as well as my benchmark assets and inflation. I found from testing my VAR models that CPI changes directly cause gold price changes, and gold price variability is partially explained by CPI movement, whereas I do not find any evidence of this nature for BTC. I found that BTC's inflation-hedging properties are weak and there would be no logical to use BTC as an inflation-hedge over more traditional assets, such as gold.

1. Introduction

The popularity of Cryptocurrencies have grown tremendously since Satoshi Nakamoto introduced the first cryptocurrency in 2008 after proposing a system for digital transaction (Nakamoto, 2008), which is now known as Bitcoin (BTC). BTC has often been referred to as the 'digital gold' as per Taskinsoy (2021), who argues that the most common trait between BTC and gold is that the price of the assets are not controlled by central banks and the price is completely determined by the demand for the asset. The key difference between gold and BTC is that there is total fixed amount of BTC of 21 million, with just under 19 million BTC's in circulation at the time of the research by Taskinsoy (2021). Due to the fixed supply of BTC and the fact that BTC is commonly referred to as the new digital gold, there is a lot of debate and interest around the inflation-hedging properties, given that investors have commonly used gold as an inflation-hedge (Baur and McDermott, 2010).

The question as to whether cryptocurrencies, specifically BTC, can be considered an inflation-hedge is an interesting topic, as cryptocurrencies are still very much in their infancy and are still a long way off maturing as an asset class and ultimately showing evidence of being able to hedge against inflation in the long-run. According to data published by Statista.com (2022), there were 10,397 cryptocurrencies worldwide in February 2022, compared to 66 in 2013, the most well-known of course being BTC. Due to the immaturity of BTC. the debate around how BTC is categorised in terms of its asset class is something that can be found in many scholar publications, which is a particularly important topic when considering an inflation-hedge. My assumptions based on my knowledge on the topic are that due to the staggering growth of BTC from inception of BTC when prices started trading at $0 to a price exceeding $64,863 in April 2021 (Taskinsoy, 2021), investors from inception have more than hedged against inflation, they would likely have experienced unrivalled returns in comparison to other asset classes during this time. However, I expect to find that after the initial stages of growth and once some sort of average price is found over a sustained period, the asset will experience from higher levels of volatility in comparison to other assets traditionally used to hedge-inflation, such as gold. My understanding of BTC is that it is a speculative asset, whereby investors bet on prices to go up or down to make profits, which ultimately increases volatility. I would also expect to find that BTC prices are less impacted by monetary policy changes or economic crisis, given that the asset is not controlled by a central bank and is largely driven by speculative investors, which would lead to more stable prices in times of economic crisis, and add to weight to the argument that BTC has inflation-hedging properties.

The research I conducted aims to look at the inflation hedging properties of BTC to answer the question as to whether BTC can be considered an inflation-hedge. I will achieve this by reviewing literature on this topic to gain an understanding on the different views on BTC's inflation-hedging properties, and how this is measured. The review of the literature from reputable scholars will provide me with insight and either prove or disprove the assumptions I have made on the topic and results that I expect to see. The successful review of literature will give me a clear idea on the direction of my study and the different considerations needed to put together a well-constructed methodology that details how I answer the research question; is BTC an inflation-hedge. I can then

2. Literature review

Before I begin to look at different scholars views on whether BTC is an inflation-hedge, I need to understand what cryptocurrencies are, what BTC is, and why I have chosen to look at the inflation-hedging properties of BTC as appose to other cryptocurrencies. Wolfgang et al (2020) refer to cryptocurrency as a type of digital asset that uses distributed ledger, or blockchain, technology to enable a secure transaction. A question that is often asked is how cryptocurrency differs to other asset classes or instruments such as fiat money, securities, or commodities. Whereas fiat money is a government issued currency that is not backed by a commodity, cryptocurrency is an encrypted digital currency which cannot be materialized as stated by Hassani et al (2018). Hassani et al (2018) paper discusses the most important features of cryptocurrency, that being that cryptocurrencies trade peer-to-peer, in other words the transaction takes place directly between the buyer and the seller, which is a result of decentralized control and independent of any government or monetary authority.

As defined by Wolfgang et al (2020) Blockchain technology is used to enable a secure transaction when buying/selling cryptocurrency. Blockchain technology has ensured the buyers and sellers in the cryptocurrency transactions (the traders) remain anonymous, the records are irreversible and there is no risk of the double spending problem. A recent website publication from PWC (n.d.) states that blockchain is a decentralized ledger of all transactions across a peer-to-peer network. Using this technology, participants can confirm transactions without a need for a central clearing authority (PWC, n.d.). This decentralised ledger of transactions means that records are irreversible as no data can ever be removed from a blockchain. In addition, recording transactions on a blockchain will prevent the double spending problem, which is where the “same single digital token can be spent more than once, and this is possible because a digital token consists of a digital file that can be duplicated or falsified” Chohan (2021).

Osterrieder et al (2016) publication states that Bitcoin became the first decentralized cryptocurrency in 2009 and in the largest in terms of market cap, representing more than 81% of the total cryptocurrency market, as per data published by CoinMarketCap in 2016. As per CoinMarketCap in Q3 2022 Bitcoin has a market capitalisation of $368 billion, with Ethereum having the second highest portion of market capitalisation of $160 billion, ~57% less than Bitcoin. As mentioned, Bitcoin is a decentralised cryptocurrency, this means that Bitcoin is shielded from government manipulation or interference as per Osterrieder et al (2016). This is one of the reasons why Bitcoin can be used as a hedge against inflation, as central bank and governing bodies cannot manipulate it, unlike the supply of a fiat currency. For this reason, BTC has often to been referred to as the ‘digital gold’, which has been widely contested amongst scholars such as Selmi et al (2022), Taskinsoy (2021) and Uddin et al (2020).

When evaluating BTC’s inflation-hedging properties it is important to understand how BTC is categorised in terms of its asset class, for example, is BTC a currency, commodity, security or even its own asset class. Yermack (2013) argues that the elevated levels of volatility associated with BTC prices is more consistent with the behaviour of a speculative investment than that of a currency, which is in line with my assumption on how BTC is defined in terms of asset class. Yermack’s research compared EUR, JPY, CHF, and GBP currencies volatility against the USD, using data from January 2013 to November 2013. The findings were that the year-to-date volatility of these currencies paired with USD ranged between 8-12%, whereas BTC-USD exchange rate volatility was 133%. The BTC market has of course matured significantly since the time of this study, and I will of course be looking at the USD inflation relationship with BTC prices in my project analysis. Gronwald (2019) paper looks at whether BTC can be considered a commodity, by applying GARCH models to the data, to help identify similarities in the risk/volatility in the asset returns between BTC and various commodities. The findings from Gronwald are that BTC shares properties to that of exhaustible commodities and that BTC price dynamics are influenced by extreme market movements, and this influence is larger than in crude oil and gold markets, which is early evidence that Bitcoin is not the digital gold in terms of price dynamics. Moreover, Alberts and Bertrand (2015) paper states that as per the definition of a ‘security’ under the Securities Act, BTC is not a security and BTC does not fall within the definition of any common type of security. Baur et al (2018) paper focuses on whether BTC is a medium of exchange or speculative asset and finds that BTC is a hybrid of a fiat currency and a commodity. Baur et al find that BTC is uncorrelated with stocks, bonds, and commodities, and these findings are true in both stable and unstable economic periods. The findings are consistent with Gronwald (2019) and Alberts and Bertrand (2015) in as much that the properties of BTC differ to stocks and commodities. Therefore, it still remains unclear as to how BTC is categorised in terms of its asset class, but the argument and general consensus is that BTC is its own asset class and is used as a speculative investment and not as an alternative to currency or other traditional asset class.

In order to answer my research question, if BTC is an inflation hedge, I need to understand the how inflation is defined and how inflation is handled by the government (Federal Reserve). Inflation is defined as a process of continuously rising prices, or equivalently, of a continuously falling value of money as per Parkin (2008). Arnold and Auer (2015) speak to consumer price indices (CPIs) and how analysing the growth of rates of CPIs are a natural way to measure inflation. Arnold and Auer (2015) also reference studies that look at price indices (PPI), wholesale price indices (WPI), retail price indices (RPI) or GDP deflators to measure inflation. In terms of time series data analysis, inflation related studies typically focus on monthly, quarterly, bi-annual, or annual period-to-period inflation data. In the United States inflation levels are influenced by monetary policy changes which are controlled by Federal Reserve policymakers. The Federal Open Market Committee (FOMC) set out that long run inflation of 2% is consistent with the Federal Reserve's mandate as per Board of Governors of the Federal Reserve System, (2020). Sustained levels of high or low inflation reflect output gaps in the economy and thus requires intervention from The Federal Reserve in the form of monetary policy change to reduce the output gap. This is known as the Taylor Rule, which is a "simple monetary policy rule that prescribe how a central bank should adjust its interest rate policy instrument in a systematic manner in response to developments in inflation and macroeconomic activity" (Orphanides, 2007). In periods of high inflation, monetary policy policymakers will increase interest rates to discourage borrowing and incentivise saving, which in turn will reduce spending and decrease inflation, this is known as contractionary monetary policy. The exact opposite is true in periods of low inflation, interest rates are lowered to encourage borrowing and spending in attempt to stimulate the economy, this is known as expansionary monetary policy. Adjustments to monetary policy to help manage inflation can also be achieved through quantitative easing (QE) and quantitative tightening (QF), which involves increasing and decreasing the money supply in the economy by the Federal Reserve purchasing or selling government and corporate bonds. Hofmann et al (2021) argue that quantitative easing can partially substitute for interest rate easing and has the potential to maintain target inflation rates as defined by the Federal Reserve. Therefore, in periods of increasing and sustained inflation, it is important for investors to find value outside of the falling value of USD whilst monetary policy changes work to close the output gap and reduce inflation as per the Taylor Rule, which leads to the need to hedge against inflation for investors.

Fisher (1930) was the first to find that there is a hypothetical relationship between asset returns and inflation. Fisher found that the sum of expected real return of an asset and expected inflation could be expressed as the nominal interest rate. Research from Fama and Schwert (1977) builds on the research from Fisher (1930), and states that unexpected inflation should be considered as well as expected inflation, which is something that was not considered in Fisher's initial research. Therefore, these findings from Fisher suggested that there are viable solutions for investors to protect themselves against continuously rising prices, or continuously falling value of money, these solutions are of course widely contested and there is a plethora of different publications and theories on the most effective methods to hedge against inflation. I will look at literature that argues for and against my research question as to whether BTC is an inflation-hedge.

Bodie (1976) published thought-provoking literature on the topic of inflation-hedging, with the focus on how inflation-hedging is defined. Bodie stated that there are three definitions of inflation hedging. The first is that a security can only be an inflation hedge if it eliminates or reduces the possibility that the real return on the security will fall below a specified floor value. The second definition relates to how measuring the hedging effectiveness of a security as the proportional reduction in the variance of the real returns on a default-free bond attainable by combining the security and the bond. Finally, and arguably the most common definition of an inflation hedge, is whereby an asset can only be an inflation hedge if a positive correlation between the nominal return of the hedging asset and inflation. These definitions by Brodie will help me to identify whether BTC is an effective inflation-hedge when it comes to analysing my results.

My research on analysing the inflation hedging properties of Bitcoin is not new and there are many publications on Bitcoin as an inflation-hedge. However, my aim is to compare other scholars results and methods used and implemented to explore the inflation hedging properties of BTC. This will allow me to assess the strengths, weaknesses, and gaps of existing literature. To begin with, it is important understand why BTC is widely considered an inflation hedge and why this is widely debated. One of the main reasons is due to the limited supply of BTC, Franco (2015) states that BTC is deflationary because of its fixed money supply. Unlike other fiat currencies, BTC has a fixed supply of 21-million coins and therefore as long as demand remains consistent, the value of BTC will increase over time, which in turn leads to the conclusion from Franco that BTC is deflationary and was designed in this way to eliminate inflation. The publication from Franco (2015) is consistent with my assumption on BTC in as much that I believe that BTC is not impacted by monetary policy changes or governmental interference.

Ciaian et al (2016), Choi & Shin (2022) both find a positive link/relationship between BTC prices and inflation, which adds weights to Franco (2015) publication that BTC can be used to eliminate inflation. Ciaian et al (2016) study based on the money demand theory explain how exchange rates may reflect inflationary development and thus impact positively Bitcoin price, meaning there is a positive relationship between inflation and BTC prices. Choi & Shin (2022) argue that despite Ciaian et al (2016) research providing a link between inflation and the price of Bitcoin, the link has not been tested empirically. Choi & Shin (2022) empirical analysis results obtained by using VAR model, show that Bitcoin prices increase significantly after a positive inflation shock, suggesting that Bitcoin could be a useful hedge against inflation. The empirical analysis undertaken by Choi & Shin (2022) looks at the response of Bitcoin to the one-standard-deviation shock in inflation and their 90% confidence band. However, the inflation-hedging property has not been directly tested due to the lack of realized inflation data at a high frequency. I aim to build on the research and findings of Choi & Shin (2022) by utilising new/realized inflation data that is available post publishing of the research by Choi & Shin (2022) with a higher frequency of inflation data in recent times (2022). It is also worth noting that as part of the VAR model implemented in Choi & Shin (2022) research, they did not look at Granger-causality to see if there is direct causation between BTC and inflation, and if so, what is the direction of this causation i.e., does changes in BTC price cause inflation movement or vice versa.

Blau et al (2021) also found a positive relationship between BTC prices and inflation by adopting a VAR model, similarly to Choi & Shin (2022). The paper look at the time-series relationship between BTC and forward inflation rates and find that changes in BTC cause changes in the forward inflation rate. However, changing interest rates are not the cause of change in BTC price, thus movements in Bitcoin precede changes in expected inflation. Unlike the research of Choi & Shin (2022), Blau et al (2021) use the Granger-causality test to find that BTC Granger-cause forward inflation rates. The findings from Blau et al reject the theory that the positive relationship between BTC and inflation is driven by the onset of the COVID-19 pandemic and argue that inflation-hedging properties are evident prior to the onset of COVID-19. Similarly, to Blau et al (2021) research, Conlon et al (2021) find a positive relationship between the price of BTC and forward inflation rates using a wavelet time-scale technique. However, in contrast to Blau et al. (2021), empirical findings from Conlon et al. (2021) only find a brief positive relationship between forward inflation expectations and Bitcoin which coincide with the initial stages of COVID-19, and there is only limited evidence outside of this period that suggest that BTC is an effective inflation-hedge. Conlon et al. (2021) conclude that “while a transitory link between cryptocurrencies and forward inflation expectations is evident, the absence of consistent hedging properties may be a cause for alarm as investors attempt to find storage of value outside of traditional mechanisms”. The findings of Conlon are inconsistent with my assumption/belief that BTC is not influenced by monetary stimulus, as the research finds a positive link between BTC prices and inflation post the onset of COVID-19.

Therefore, I have established from critically evaluating the literature that Blau et al (2021) reject the argument that the onset of COVID-19 is the cause of the brief positive relationship between inflation and BTC prices, whereas Conlon et al (2021) directly oppose this view and state that the COVID-19 onset is the cause of the brief positive relationship between BTC and forward inflation. Conlon et al (2021) state that as a result of the COVID-19 crisis, many countries began to implement 'aggressive' monetary stimulus to support the economies, which implies that monetary policy changes influence BTC prices. This contradicts Osterrieder et al (2016) belief that that BTC is shielded from government manipulation or interference. In addition, Ma et al (2022) research finds that monetary policy shocks result in a strong reaction in BTC prices, and these results have an even greater impact on BTC prices in a bull-market, which is further evidence that BTC prices are not 'shielded' from government interference (Osterrieder et al, 2016). Corbet et al (2017) findings are somewhat similar to that of Ma et al (2022) in as much that BTC prices are influenced by interest rate adjustments, despite the fact that BTC is a decentralized asset that is free from government influence and manipulation. The contrasting findings from Blau et al (2021) and Conlon et al (2021) presented me with an opportunity to explore further the impact of COVID-19 on the effectiveness of BTC as an inflation-hedge, which by extension means I will also need to look at monetary policy shocks/changes which are caused by COVID-19 onset as per Conlon et al (2021). Through my analysis I will be able to establish if BTC prices have been driven by monetary policy shocks and if a positive relationship between BTC prices and inflation exists prior to the period of monetary stimulus that occurred as a result of COVID-19.

From the literature reviewed util this point Ciaian et al (2016), Choi & Shin (2022), Blau et al (2021), Conlon et al (2021) do not look in depth at the high associated volatility of BTC (Shen et al, 2020) and the consequences this has on determining if BTC can be considered an inflation hedge. Dyhrberg (2016) paper on the hedging capabilities of BTC analysed the hedging properties of BTC against the FTSE 100 and the US dollar by applying GARCH methodology, which used to look at the volatility correlations of financial assets. Dyhrberg (2016) found that volatility (asset return) correlations between USD and BTC were very small and BTC/FTSE100 correlations were negative, meaning that BTC cannot be used as a hedge against USD, but can be used as a hedge against the FTSE100. The research from Dyhrberg (2016) does not provide any analysis in terms of BTC as an inflation-hedge but the literature does provide the methodology on how to evaluate an assets inflation-hedging property which was not applied in the other literature reviewed until this point. Therefore, by applying Dyhrberg (2016) methodology (GARCH modelling) to compare BTC asset returns against traditional inflation-hedging assets and inflation changes/movements, I can identify volatility correlations between BTC and traditional inflation-hedging assets and inflation itself, which helps answer my research question; 'is BTC is an inflation-hedge'.

A clear gap that has been identified in the literature I have reviewed, and that is that when assessing BTC as an inflation-hedge, the literature reviewed thus far does not look at how BTC compares against other assets or methods in terms of inflation-hedging properties. It is important that when looking at BTC as an inflation hedging method/strategy to compare against other inflation-hedging methods to determine the degree of BTC's inflation-hedging effectiveness. Therefore, it is essential to review literature to establish traditional or commonly accepted inflation-hedges, as this allows me to establish 'benchmark' assets to compare BTC against and analyse the differences and/or similarities in their inflation hedging properties, which are defined by Bodie (1976). I do not aim to answer whether benchmark assets are inflation-hedges, I simply aim to identify commonly accepted/used inflation-hedging assets and compare the inflation-hedging properties of these assets against BTC.

Baur and McDermott (2010) convey a commonly accepted view on inflation-hedging, in as much that investors have traditionally used gold as a hedge against inflation or a falling dollar. Because gold is priced in dollars, if the dollar loses value, the nominal (dollar) price of gold will tend to rise. This view is supported by numerous publications, notably Ghosh et al. (2004) and Worthington and Pahlavani (2007), which find that storage value can be found in gold against rising inflation. Ghosh et al. (2004) look at the characteristics of gold hedging versus inflation and ultimately establish that in the long-run gold is an effective hedging strategy against inflation. Ghosh et al (2004) theoretical model leads to findings that "short run movements in the price of gold are consistent with the gold price rising over time with the general rate of inflation". These findings were found by looking at the price of gold (USD) and US inflation rates. Worthington and Pahlavani (2007) considered structural changes to the gold market and inflationary regimes when analysing the relationship between the price of gold in USD and US inflation between the years of 1945 and 2006. Worthington and Pahlavani (2007) conclusions from their research was that gold is a useful inflation-hedge in the post-war and post-1970s period The period during the 1970's did not see such a strong correlation between gold prices and inflation due to the collapse of the Bretton Woods system. Moreover, Van Hoang et al (2016) found that gold can be used as a method for hedging against inflation. However, Van Hoang et al (2016) who consider the nonlinearity, short-run, and long-run asymmetries in their study of gold as an inflation hedge in in several countries found that gold is not a long-run inflation-hedge in the US. However, it can be used as a short-run inflation-hedge, whereas Ghosh et al (2004) found that gold hedges against inflation in the long-run. Hoang et al (2016) argue that investors should better invest in gold for its ability to reduce the portfolio risk than for its ability to hedge against inflation which is supported by other reputable studies such as Choudhry et al. (2015) and Hammoudeh et al. (2013)

There is often debate and question as to whether gold is a more effective inflation-hedge than other commodities, such as other precious metals, energy products, livestock, or agricultural products. Bampinas and Panagiotidis (2015) study the data on consumer prices (inflation), gold prices and silver prices both in the UK and US over a period between 1971-2010. The time parameters for this research are very wide, with just under 40 years of realised data. The research found that in the US and the UK, gold is a better inflation hedge than silver and that the long-run relationship of gold against expected inflation became more stable over the last decades. Ivanov (2017) research focuses widens the scope of the research and looks at the performance of stocks, bonds, oil indexes and real estate as well as commodities against inflation. The research from Ivanov (2017) found that oil, gold, and corn are all good inflation-hedges, whilst stocks, soy, and beef are not hedges against inflation. These findings add weight to the view that gold is the most commonly used asset to hedge against inflation.

Arnold and Auer (2015) argue that even though gold is typically considered the ideal hedge due to its ability to hold value through periods of economic turmoil, the long-run equilibrium between stocks and inflation offers protection against inflation that gold is not able to. Therefore, Arnold and Auer (2015) findings are that inflation is an effective inflation-hedge in the long run (greater than 5 years) which contradicts the findings of Ivanov (2017) who stated that stocks are not hedges against inflation. In addition, Bampinas and Panagiotidis (2016) found that stock market investment can provide a hedge against inflation. This research focused on individual stocks (1993-2012) as opposed to stock market indices. The findings from this research conveyed that the energy and industrials sectors tend to be the most effective stocks to invest in to hedge against inflation. Classical economic theories from scholars Fisher (1930) and Gordon (1959) are consistent with the view that stock returns are a hedge against inflation and expected inflation in theory should increase expected dividend returns However, more recent literature from has rejected the hypotheses by Fisher (1930) and Gordon (1959) that stocks can be used as an inflation-hedge, with both Lintner (1975) and Donald (1975) arguing that there is a negative relationship between inflation and equity prices. Eldomiaty (2020) consider the contrasting theories of Fisher (1930), Gordon (1959), Lintner (1975) and Donald (1975) to analyse the effect of inflation rates on NASDAQ100 (NDX) and DIJA30 stock indices from 1999-2016. Eldomiaty (2020) found that NDX and DIJA30 stock price changes and inflation rate changes have a negative relationship.

There are contrasting views from the literature reviewed as to whether gold and stocks can be considered inflation-hedges, and there will always be opposing views on how effective an asset is at hedging against inflation. The review of literature on gold and stocks as inflation-hedges gives me reasoning as to why these assets can be used to function as a benchmark to measure BTC inflation-hedging properties against.

3. Methodology

3.1. Research Philosophy

I have adopted a positivist philosophy in order to answer my research question, which is the 'focus on strictly scientific empiricist method designed to yield pure data and facts uninfluenced by human interpretation or bias" (Sanders et al, 2015). I have looked at the ontological, epistemological, and axiological assumptions that underpin my research philosophy to determine that I am using a positivist research philosophy. In terms of the ontological assumptions, I am looking a real independent data to determine if BTC is an inflation hedge by looking at the inflation-hedging characteristics defined by Bodie (1976), and building on the weaknesses, strengths and gaps identified from my literature review. In terms of my results from my analysis, the reality of these results is the same for any person who were to observe or measure these. The epistemology assumptions of my research are that scientific methods, quantitative data, observable and measurable facts constitute acceptable knowledge. Therefore, I have used epistemological assumptions as my research involves a hypothesis being tested to establish if the hypotheses can be confirmed (in full or part) or rejected i.e., confirming if BTC is an inflation-hedge (in full or part) or not an inflation-hedge. In terms of the axiological assumptions, in my research I have analysed secondary data that is quantitative which is measurable and quantifiable, thus removing bias. I have remained neutral and not influenced my findings based off pre-existing values or beliefs. This is consistent with the axiological assumption that underpins positivist research.

3.2. Approach to Theory Development

In terms of theory development, I have taken a deductive approach to answer my research question, which involved collecting and analysing data to test my theory. The theory I am testing comes from my research question and by extension, my literature review, whereby I have established different scholars theories on whether or not BTC is an inflation-hedge. I have implemented Blaikie (2019) six sequential steps to answer my research question through a deductive approach:

1. I have put forward a hypothesis that BTC can be used to hedge inflation. This sets out a testable proposition of the relationship between BTC prices and inflation variables.
2. I have used literature to deduce a number of testable propositions. I found from my literature review that there were varying views on whether BTC is an inflation-hedge and different methods to use to deduce if BTC can be used as an inflation hedge.
3. I examined the premise of the different literature and critically evaluated these against other publications/theories to find advanced understandings.
4. I tested the hypothesis that BTC can be used to hedge inflation by collecting data to measure the relationship between the two variables and analysing my findings.
5. I found that the results of the analysis are not consistent with the hypothesis that BTC is an inflation hedge.
6. I am unable to corroborate the results of my analysis and my hypothesis that BTC is an inflation-hedge, and thus reject the hypothesis as per step 5.

3.3. Methodological Choice

In terms of my research design, I have established that I am adopting a positivist philosophy and deductive approach with the aim of testing a theory; is BTC an inflation hedge. Therefore, I have selected a quantitative methodology to answer my research question. My research question focuses on establishing if BTC can hedge against inflation with the focus being United States centric. This involved research focusing on examining the relationship between BTC price (USD) movements, US inflation and comparing the inflation-hedging properties against a benchmark, which I established from my literature review will be gold prices and US stock prices. I have used I have not looked at whether gold or stocks are effective hedges against inflation within the scope of my research, I am simply using these variables as a benchmark as a result of the findings from my literature review that these are commonly used assets to hedge against inflation. I have measured the inflation-hedging properties numerically and have completed my analysis using statistical and graphical techniques and thus, as per Sanders et al (2015) definition of quantitative research characteristics. Quantitative research is often associated with positivism philosophy; hence I have already spoken to my positivist research philosophy.

3.4. Research Strategy

Establishing the research strategy is a key layer in my ‘research onion.’ The research strategy is how I have answered my research question, by setting out a plan of action to achieve the end goal and is affected by my methodological choice. I have adopted an archival strategy in order to answer my research question, which in my case relates to the collection of historical quantitative secondary data. I have focused on analysing historical secondary data looking at the past events of BTC, gold and NDX prices and comparing this against inflation related variables and also considering other macroeconomic variables, interest rates, bond yield and unemployment. The benefit using an archival research strategy is that there is a plethora of secondary data to utilise and analyse without having to collect the data results independently (primary data). I have also applied an experiment research strategy as I am looking at the relationship between variables as part of the VAR model. I am testing the impact that a change in the independent variable has on another variable, which is what is being done in the Granger-causality, impulse response function and variance decomposition tests. This shows me the causation between and the direction of information flow between my variables and has helped me answer whether BTC hedges against inflation. My focus is a mono-method quantitative study as I have used a single data collection technique. The data I have used is of a numerical nature which I have analysed using a data analysis technique by using a vector autoregressive statistical model. I have used secondary data collection methods to obtain quantitative time series data on BTC prices, gold prices, NDX prices, and US macroeconomic data.

3.5. Time Horizon

Regarding the time horizon of my research, I have focused on a longitudinal study as appose to a cross sectional study. Whereas a cross-sectional study will focus on a snapshot at a point in time, a longitudinal study will look at the observations over a period of time. It is essential to focus on a longitudinal study to answer my research question as I will need to assess the BTC, gold and NDX prices and US macroeconomic data over time as appose to a snapshot of BTC price and inflation at a given time. A longitudinal study enabled me to establish the relationship of the variables over a specified period of time and identify the change and development of the variables. I would only be able to see if BTC hedges against inflation at a particular time with a cross0sectional study, whereas a longitudinal study allows me to look at the volatility time varying correlation and capture the relationship between BTC and inflation (and the benchmark variables) as they change over time, whilst looking at their past values.

3.6. Data Collection

BTC price data has been obtained from the “Top 100 Cryptocurrencies Historical Dataset” from Kaggle. I have only used the Bitcoin specific dataset (ignored other cryptocurrencies as they are out of scope) which has been scraped from www.investing.com. The dataset ranges from 18th July 2010 to 23rd August 2022 and looks at the daily open, high, low, close prices as well as the daily trading volume and currency, which is always US Dollar (USD). I will only keep the dates and daily open price for BTC as I know the data is US specific, the daily trading volume is not needed as part of my analysis as the demand for BTC is reflected in the price of the asset and high, low, and close price are just unnecessary noise. I have chosen to focus my research question on BTC as appose to other cryptocurrencies as I feel is most representative of the cryptocurrency market as a whole, and one that has the most existing literature when it comes to analysing the effectiveness of hedging against inflation. In addition, BTC was the first decentralised cryptocurrency is 2009 and has become the most well-established cryptocurrency during this time, having an overwhelming market share in terms of market capitalisation. BTC is the most mature cryptocurrency which means there is more realized data that will allow for meaningful analysis and accurate results. I found that there was contrasting views on the effectiveness of BTC as an inflation hedge when conducting my literature review. Ciaian et al (2016), Choi & Shin (2022) and Blau et al. (2021) is that the price of BTC is positively related to inflation, and thus has inflation-hedging properties. However, Conlon et al (2021) argue that despite seeing a positive correlation between BTC prices and inflation, this has only been observed due to the onset of Covid-19. The contrasting findings creates ambiguity and an opportunity for further exploration and research within my studies.

For the benchmark data, I have used the daily spot gold prices (USD/oz) from Kaggle which includes daily open, high, low and close prices as well as daily trading volume from 4th January 2000 to 2nd September 2022 and currency, although I will only need to keep the dates and daily open price, for the same reasons I have given above for BTC daily prices. I have chosen gold as a benchmark to compare BTC inflation-hedging properties, which is based off the findings from my literature review. Baur and McDermott (2010), Ghosh et al. (2004), Worthington and Pahlavani (2007) and Bampinas and Panagiotidis (2015) found that gold can be considered as inflation-hedging asset. Ghosh et al (2004) findings were that long-run gold is an effective hedging strategy against inflation, Worthing and Pahlavani (2007) established that gold is an effective inflation-hedging strategy in the post war (World War II) and 1970's periods and Bampinas and Panagiotidis (2015) found that gold was a more effective inflation-hedge than silver in the US and UK. However, Ivanov (2017) argues that gold is only a 'partial' inflation-hedge, whilst oil and corn being 'complete' inflation-hedging methods.

Daily NDX data has been gathered from Yahoo Finance, and includes the daily open, high, low, close, and adjusted close prices as well as the daily trading volume from 24th January 2001 to 22nd December 2002. Again, I will only look at the daily open price and corresponding date. I have also chosen to compare the inflation-hedging properties of BTC against stocks, specifically the Nasdaq 100 (NDX), I could have chosen any of the large US stock indices, but I have chosen NDX because I have reviewed existing literature by Eldomiaty (2020) on NDX as an inflation-hedge. It is not within the project scope for me to assess the hedging properties of NDX, but to compare BTC inflation-hedging properties against those of NDX. I have picked stocks as a benchmark as classical economic theories from scholars Fisher (1930) and Gordon (1959) are consistent with the view that stock returns are a hedge against inflation which was backed up by the findings of Arnold and Auer (2015) who found inflation is an effective inflation hedge in the long run. However, there are findings from Litner (1975) and Donald (1975) argue that there is a negative relationship between inflation and equity prices.

US macroeconomic dataset I am using has been pulled from Kaggle and has been gathered from the Federal Reserve Economic Data, OECD, and Conference Board Org. The macroeconomic dataset is monthly data and includes, inflation, CPI, GDP unemployment, mortgage interest rates and corporate bond yield variables. There were more variables as part of this dataset, but I will be removing these as they do not add value to my analysis. In order to analyse the inflation-hedging properties of BTC, I will need to consider the type of macroeconomic data I need. I found from my literature review that Arnold and Auer (2015) reference a number of studies and how the studies measured inflation. Arnold and Auer (2015) found that consumer price index (CPI) growth rates are a natural way to measure inflation, but points to other studies that look at price indices (PPI), retail price indices (RPI) and GDP deflators. I will also look at other macroeconomic data that links to monetary policy shocks/changes as a result of the findings in my literature review from Ma et al (2022) and Corbet (2017) that found that strong BTC price changes are impacted by monetary policy shocks. Monetary policy shocks/changes is something I need to consider when looking at the relationship between BTC and Inflation, and this can be identified by looking at indicators such as mortgage interest rates, bond yield and unemployment.

In terms of the reliability and validity of the data, these reliable datasets pulled from reputable sources in Kaggle and Yahoo Finance. I have spot checked the BTC data obtained from Kaggle against investing.com and the numbers are consistent. Investing.com retrieve their data from the biggest financial data providers as well as real-time market makers as per their website (investing.com, 2023). The gold data obtained from Kaggle has also been spot checked against various financial market sources to ensure the reliability of the data. The NDX daily price data from Yahoo Finance is from one of the most reputable finance sources, with near on 100% accurate pricing data. The macroeconomic data obtained from Kaggle has pulled from governmental websites, which is considered as reliable data. There are no ethical concerns with my data as these are publicly available secondary data sources.

3.7. Data Analysis

My data analysis has been completed using R software, which I have used because it is an open-source software that benefits from an array of packages and libraries, which can be seen in table 1 in chapter 4. In particular , the "vars" package is enormously powerful for building, testing, and obtaining results for VAR models. R is also great software for data visualisation, which has been essential in my project to display the behaviour of my variables over time. R is most commonly known for its unrivalled and comprehensive statistical analysis, which will be very useful for my research as I am looking at statistical model (GARCH and VAR).

In order to establish if BTC is a hedge against inflation, I have applied the theoretical concept of Fisher (1930) and examined the relationship between BTC prices and consumer price index (CPI) over a period of time and compared this to my findings on the relationship between gold prices and CPI and NDX prices and CPI. I will have applied Bodie (1976) definition of inflation-hedging properties when examining the relationship between BTC prices: i. return of asset used to hedge inflation must be greater than or equal the rate of inflation ii. asset reduces variance or uncertainty iii. inflation and asset return are positively correlated.

The first step of examining the inflation-hedging properties of BTC through my data analysis was to perform exploratory data analysis on the BTC, gold, NDX data and macroeconomic data to understand how the data is behaving by looking at the central tendencies and measures of dispersion using R. I have visualized the time series data to see how the BTC, gold and NDX compare over time and how this looks in comparison to the macroeconomic variables over time. The plotted time series data allows me to see the relationship of the asset prices BTC, gold and NDX over time. I have also compared the asset time-series plots against the macroeconomic variables that allows me to identify trends between asset prices and inflation.

Correlation analysis between BTC, gold, NDX and the macroeconomic variables allow me to ascertain if there is a relationship between these variables. The correlation analysis between BTC, gold and NDX prices will show the relationship between BTC and my benchmark assets, which is useful analysis to help me determine if BTC has inflation-hedging properties. Bodie (1976) definition of inflation-hedging is if inflation and asset return are positively correlated, thus finding the correlation between BTC prices and inflation variables is a gage for me to determine the inflation-hedging properties. Comparing the BTC and inflation variables correlation against my benchmark assets (gold and NDX) compare the inflation-hedging potential of BTC vs the benchmark(s).

I found from my literature that Ciaian et al (2016), Choi & Shin (2022), Blau et al (2021), Conlon et al (2021) do not look in depth at the high associated volatility of BTC when determining the inflation-hedging properties of the asset. This is important analysis as Bodie (1976) states that one way to define inflation-hedging is as asset reduces variance or uncertainty, which would not be the case if we are dealing with a highly volatile asset. I found that Dyhrberg (2016) and Gronwald (2019) studies uses a GARCH model to determine correlations in the financial risk/volatility of assets, which allowed for identification of shared properties between the assets. Therefore, I have used the methodology applied by Dyhrberg (2016) and Gronwald (2019) and implemented a GARCH model to profile the volatility of BTC in comparison to gold and NDX prices, specifically a Dynamic Conditional Correlation (DCC) GARCH to calculate the time varying correlations between BTC and gold/NDX asset returns as a function of the past volatility and the correlations between the assets I am comparing. I have also used DCC GARCH to look at the time varying correlations between the assets (BTC, gold, NDX) and inflation (CPI).

Similarly, to the study by Choi & Shin (2022) and Blau (2021), I have estimated vector autoregressive (VAR) models to find the relationship between BTC prices and inflation. Choi & Shin (2022) used a VAR model to reach their conclusion that BTC appreciates against inflation shocks and concludes that BTC has inflation-hedging properties. I have used a VAR model to find the relationship between BTC and inflation, and to ultimately answer my research question because VAR models are commonly used to answer similar research questions and are widely considered reliable statistical models. Zivot and Wang (2006) believe that VAR models are one of the most successful models for the analysis of timeseries data with multiple variables. The VAR model captures the relationship between variables based off their past values, which is an efficient and effective way for me to answer my research question. I have implemented my VAR model by first building the models (model 1:BTC Prices and CPI, model 2:Gold Prices and CPI and model 3:NDX Prices and CPI). I checked my data is stationary as VAR model will not give accurate results/findings if non-stationary data is present. I then check my models for structural breaks, serial corelation and heteroscedasticity to ensure my model is stable. Finally, I use different tests to interpret the results of the VAR models. I will look at granger-causality, impulse response function and variance decomposition. I found from my literature review that although Choi & Shin (2022) found BTC prices rise after an inflation shock, they did not use the Granger-causality test, which is an area of weakness I have addressed in my research. The results for my model using BTC and inflation variables enables me to compare against my benchmark models to assess the inflation-hedging properties.

4. Data Analysis

As mentioned in my methodology, I have used R to complete my data analysis, and I have used the packages and libraries as shown in table 1.

Packages	Library	Reason for Use
install.packages("pastecs")	library("pastecs")	Used to provide summary table of central tendencies.
install.packages("ggplot2")	library("ggplot2")	Used for data visualisation and creation of graphs.
install.packages("Hmisc")	library("Hmisc")	Used to plot correlation matrix In table format.
install.packages("corrplot")	library("corrplot")	Used to 'plot' aesthetically pleasing correlation matrix.
install.packages("dplyr")	library("dplyr")	Used for dataframe manipulation.
install.packages("rugarch")	library("rugarch")	Use for flexible and rich univariate GARCH modelling
install.packages("quantmod")	library("quantmod")	Used for creating financial charts, such a volatility clustering.
install.packages("xts")	library("xts")	Used to transform dataframe to time series data and allow for 'CalculateReturns' function to be used for daily stock price return.
install.packages("rmgarch")	library("rmgarch")	Used for the creation of my multivariate GARCH model.
install.packages("Rcpp")	library("Rcpp")	
install.packages("stargazer")	library("stargazer")	Used to present VAR model features in presentable table.
install.packages("urca")	library("urca")	Used to find the unit root of timeseries data.
install.packages("vars")	library("vars")	Used to build, diagnose, and test my VAR models.

Table 1. R Packages and Libraries

4.1. Exploratory Data Analysis

I read the datasets (discussed in my methodology) that focus on asset prices (BTC, Gold and NDX) into R to begin my descriptive and exploratory data analysis. Figure 1. shows that the datasets look very similar in as much that they are all made up of the date, open, high, low, and close prices of each day as well as the volume of trading for each given day. The BTC and Gold datasets also contain a column for currency whereas the NDX shows adjusted closing price. I have spot checked the currency in both the BTC and Gold datasets and this is USD throughout.

```
> #BitcoinData
> head(Data, 10)
# A tibble: 10 x 7
   Date                Open   High   Low Close Volume Currency
   <dttm>              <chr> <dbl> <dbl> <dbl>  <dbl> <chr>
 1 2010-07-18 00:00:00 -       0.1   0.1   0.1     75 USD
 2 2010-07-19 00:00:00 0.1     0.1   0.1   0.1    574 USD
 3 2010-07-20 00:00:00 0.1     0.1   0.1   0.1    262 USD
 4 2010-07-21 00:00:00 0.1     0.1   0.1   0.1    575 USD
 5 2010-07-22 00:00:00 0.1     0.1   0.1   0.1   2160 USD
 6 2010-07-23 00:00:00 0.1     0.1   0.1   0.1   2403 USD
 7 2010-07-24 00:00:00 0.1     0.1   0.1   0.1    496 USD
 8 2010-07-25 00:00:00 0.1     0.1   0.1   0.1   1551 USD
 9 2010-07-26 00:00:00 0.1     0.1   0.1   0.1    877 USD
10 2010-07-27 00:00:00 0.1     0.1   0.1   0.1   3374 USD
```

```
> #GoldData
> head(Data3, 10)
# A tibble: 10 x 7
   Date                 Open  High   Low Close Volume Currency
   <dttm>              <dbl> <dbl> <dbl> <dbl>  <dbl> <chr>
 1 2000-01-04 00:00:00  290.  290.  280   284.  21621 USD
 2 2000-01-05 00:00:00  284.  285   281   282.  25448 USD
 3 2000-01-06 00:00:00  282.  283.  280.  282.  19055 USD
 4 2000-01-07 00:00:00  282.  284.  282   283.  11266 USD
 5 2000-01-10 00:00:00  282.  284.  282.  283.  30603 USD
 6 2000-01-11 00:00:00  282.  285.  282.  284.  13500 USD
 7 2000-01-12 00:00:00  284.  285   282.  284.  17841 USD
 8 2000-01-13 00:00:00  284.  286.  283.  285.  12171 USD
 9 2000-01-14 00:00:00  285.  286.  284   285.  32339 USD
10 2000-01-18 00:00:00  286.  290.  286.  290.  28615 USD
```

```
> #Nasdaq100
> head(Data4, 10)
# A tibble: 10 x 7
   Date                 Open  High   Low Close `Adj Close`     Volume
   <dttm>              <dbl> <dbl> <dbl> <dbl>       <dbl>      <dbl>
 1 2000-01-24 00:00:00 3888. 3905. 3661. 3661.       3661. 1989050000
 2 2000-01-25 00:00:00 3667. 3759. 3591. 3759.       3759. 1743630000
 3 2000-01-26 00:00:00 3763. 3763. 3621. 3621.       3621. 1717000000
 4 2000-01-27 00:00:00 3629. 3701. 3512. 3593.       3593. 1798460000
 5 2000-01-28 00:00:00 3596. 3618. 3408. 3446.       3446. 1616370000
 6 2000-01-31 00:00:00 3438. 3571. 3349. 3570.       3570. 1507630000
 7 2000-02-01 00:00:00 3580. 3704. 3545. 3702.       3702. 1398240000
 8 2000-02-02 00:00:00 3700. 3785. 3694. 3724.       3724. 1527880000
 9 2000-02-03 00:00:00 3726. 3857. 3704. 3851.       3851. 1722330000
10 2000-02-04 00:00:00 3859. 3930. 3857. 3874.       3874. 1751450000
```

Figure 1. Asset Prices Dataset (BTC, Gold, NDX)

The head function (Figure 1) also allows me to check the data type for each of the columns/variables. The price variables all show as double other than the BTC open price which is 'chr', the dates as 'dttm' and currency as 'chr'. Therefore, the only correction that needs to be made is to convert the BTC open price to a numeric ('dbl') value.

As mentioned in my methodology, I am removing the "Close," "High" and "Low" variables, as shown in Figure 1 to reduce the unnecessary noise in the analysis and focus only on the "Open" price. Finally, I have removed the currency character values from BTC and gold datasets as I have already established that this is all USD centric data. Therefore, I am left with the date and open price for BTC, gold and NDX data, as shown in Figure 2

I also did a check for NA's in the dataset, which returned one missing value across the three datasets, which was identified in the BTC open price, which I could clearly see from my 'head' function that this was in the first row of data. Therefore, I simply removed the first line from the BTC dataframe.

```
> #BitcoinData
> Data <- Data[,-c(3,4,5,6,7)]
> head(Data, 10)
# A tibble: 10 x 2
   Date                 Open
   <dttm>              <dbl>
 1 2010-07-18 00:00:00  NA
 2 2010-07-19 00:00:00   0.1
 3 2010-07-20 00:00:00   0.1
 4 2010-07-21 00:00:00   0.1
 5 2010-07-22 00:00:00   0.1
 6 2010-07-23 00:00:00   0.1
 7 2010-07-24 00:00:00   0.1
 8 2010-07-25 00:00:00   0.1
 9 2010-07-26 00:00:00   0.1
10 2010-07-27 00:00:00   0.1

> #GoldData
> Data3 <- Data3[,-c(3,4,5,6,7)]
> head(Data3, 10)
# A tibble: 10 x 2
   Date                 Open
   <dttm>              <dbl>
 1 2000-01-04 00:00:00  290.
 2 2000-01-05 00:00:00  284.
 3 2000-01-06 00:00:00  282.
 4 2000-01-07 00:00:00  282.
 5 2000-01-10 00:00:00  282.
 6 2000-01-11 00:00:00  282.
 7 2000-01-12 00:00:00  284.
 8 2000-01-13 00:00:00  284.
 9 2000-01-14 00:00:00  285.
10 2000-01-18 00:00:00  286.

> #Nasdaq100
> Data4 <- Data4[,-c(3,4,5,6,7)]
> head(Data4, 10)
# A tibble: 10 x 2
   Date                 Open
   <dttm>              <dbl>
 1 2000-01-24 00:00:00 3888.
 2 2000-01-25 00:00:00 3667.
 3 2000-01-26 00:00:00 3763.
 4 2000-01-27 00:00:00 3629.
 5 2000-01-28 00:00:00 3596.
 6 2000-01-31 00:00:00 3438.
 7 2000-02-01 00:00:00 3580.
 8 2000-02-02 00:00:00 3700.
 9 2000-02-03 00:00:00 3726.
10 2000-02-04 00:00:00 3859.
```

Figure 2. Removing Variables from Datasets

I have used the summary table (Figure 3) which provides an overview of the min, first and third quartiles, median, mean, and max values and will give us an idea of how this data is behaving.

I found from the summary function that the BTC data starts from July 2010 and ends August 2022. The open price variable minimum price was 0.1 USD with a record high price of 67,528.70 USD. The drastic difference between the median (684.90 USD) and mean (8,304.10 USD) suggests that we are dealing with positively skewed data. In addition, we can see that the difference between the min and the first quartile is only 122 USD, whereas the difference between the third quartile and the max value is ~ 58,600 USD, which indicates that we could have outliers in the data or extremely high values with a low frequency.

The gold data I have used ranges from January 2000 to September 2022, which is more than ten years' worth of data more than BTC, which is obviously due to the fact that BTC became decentralised asset in 2009. In contrast to BTC data, the gold data indicates more evenly distributed data with the open price mean and median values close together. However, the difference between the third quartile and max open price values convey there could be outliers in the data, this will be clearer when I visualize the data.

The findings for NDX price data are similar to that of gold in as much that there is a sizeable difference between the third quartile and max values but on the contrary has a median value lower than that of mean, suggesting that the data is positively skewed with a high frequency of data clustered around the left tail. The NDX dates range from January 2000 to December 2022. When comparing BTC, gold and NDX data it is clear that I am working with a higher frequency of gold and NDX data and thus my result may result in more accurate forecasting and analysis of gold and NDX prices than BTC.

```
> #BitcoinData
> summary(Data)
      Date                          Open
 Min.   :2010-07-19 00:00:00   Min.   :    0.1
 1st Qu.:2013-07-27 12:00:00   1st Qu.:  122.7
 Median :2016-08-05 00:00:00   Median :  684.9
 Mean   :2016-08-05 00:00:00   Mean   : 8304.1
 3rd Qu.:2019-08-14 12:00:00   3rd Qu.: 8880.0
 Max.   :2022-08-23 00:00:00   Max.   :67528.7

> #GoldData
> summary(Data3)
      Date                          Open
 Min.   :2000-01-04 00:00:00   Min.   : 256.6
 1st Qu.:2005-09-19 12:00:00   1st Qu.: 459.9
 Median :2011-05-10 00:00:00   Median :1188.8
 Mean   :2011-05-10 13:12:05   Mean   :1040.4
 3rd Qu.:2017-01-04 12:00:00   3rd Qu.:1381.4
 Max.   :2022-09-02 00:00:00   Max.   :2076.4

> #Nasdaq100
> summary(Data4)
      Date                          Open
 Min.   :2000-01-24 00:00:00   Min.   :  800.9
 1st Qu.:2005-10-17 18:00:00   1st Qu.: 1662.2
 Median :2011-07-11 12:00:00   Median : 2630.5
 Mean   :2011-07-11 06:20:13   Mean   : 4268.9
 3rd Qu.:2017-04-03 06:00:00   3rd Qu.: 5414.3
 Max.   :2022-12-22 00:00:00   Max.   :16644.8
```

Figure 3. Central Tendencies for BTC, Gold and NDX

I used stat.desc function from the pastecs library to see the measures of dispersion for the variables in the BTC, Gold and NDX datasets, shown in Figure 4 below. I first look at the standard error of the mean (SEM) for the open price of BTC, Gold and NDX. The SEM shows that the sample mean is within 219.62 USD of the population mean for BTC price, 6.86 USD for gold price and 4926. USD for NDX price. This shows that the sample mean value for all three variables is within 2.63%, 0.65% and 1.14% of their respective population means. The low SEM values show that the samples are efficient, accurate and consistent.

The 95% confidence interval for the mean CI.mean for BTC, Gold and NDX price is 430.6, 13.5 and 96.6, respectively. This tells me that the CI.mean is more stable for the gold price than that of NDX and BTC. Higher variability in the data or smaller sample sizes result in larger CI.mean values. The BTC dataset is fairly large with 4,419 lines of data, which suggests to me the CI.mean value for BTC price is larger than that of gold and NDX due to higher variability in data.

BTC price has a higher standard deviation than that of gold and NDX, which shows that the data is more dispersed and not clustered around the mean. The coefficient of variation shows me the ratio of the standard deviation in relation to its mean for each variable. This means that the coefficient of variation is a standardized and unitless measure that allows me to compare the price for all three assets, in a way that comparing the standard deviation is not able to. The coefficient of variation for BTC is 3.5 and 2 times greater than that of the price of gold and NDX, respectively. This shows that BTC is the most volatile asset out of the three and NDX is more volatile than gold.

```
> #BitcoinData
> stat.desc(Data)
                                 Date            Open
nbr.val                 4419.00000000     4419.000000
nbr.null                   0.00000000        0.000000
nbr.na                     0.00000000        0.000000
min               1279497600.00000000        0.100000
max               1661212800.00000000    67528.700000
range              381715200.00000000    67528.600000
sum            6497499628800.00000000 36695820.600000
median            1470355200.00000000      684.900000
mean              1470355200.00000000     8304.100611
SE.mean              1658189.85643985      219.622320
CI.mean.0.95         3250883.01283368      430.569796
var         12150454118400000.00000000 213145884.123125
std.dev            110229098.32888955    14599.516572
coef.var                   0.07496767        1.758109
```

```
> #GoldData
> stat.desc(Data3)
                                Date           Open
nbr.val                 5703.0000000   5703.0000000
nbr.null                   0.0000000      0.0000000
nbr.na                     0.0000000      0.0000000
min                946944000.0000000    256.6000000
max               1662076800.0000000   2076.4000000
range              715132800.0000000   1819.8000000
sum            7442603913600.0000000 5933303.2000000
median            1304985600.0000000   1188.8000000
mean              1305033125.3024724   1040.3828161
SE.mean              2731432.5022527      6.8689840
CI.mean.0.95         5354645.9582955     13.4658197
var         42548506202408144.0000000 269084.3161691
std.dev            206272892.5535494    518.7333768
coef.var                   0.1580595      0.4985986
```

```
> #Nasdaq100
> stat.desc(Data4)
                               Date           Open
nbr.val                 5768.000000     5768.00000
nbr.null                   0.000000        0.00000
nbr.na                     0.000000        0.00000
min                948672000.000000      800.91998
max               1671667200.000000    16644.76953
range              722995200.000000    15843.84955
sum            7558186550400.000000 24623048.36143
median            1310385600.000000     2630.45996
mean              1310365213.314841     4268.90575
SE.mean              2749274.466420       49.26079
CI.mean.0.95         5389610.092731       96.56964
var         43597486208993064.000000 13996775.58146
std.dev            208800110.653690     3741.22648
coef.var                   0.159345        0.87639
```

Figure 4. Measures of Dispersion for BTC, Gold and NDX

Figure 5. below shows the histograms plotted using R to show the frequency distribution of BTC, gold and NDX prices. I already had an idea how the data would look visually from the measures of dispersion and central tendencies. Both BTC and NDX prices are positively skewed with data clustered around the left tail, whereas gold price data shows a bimodal distribution with two distinct peaks.

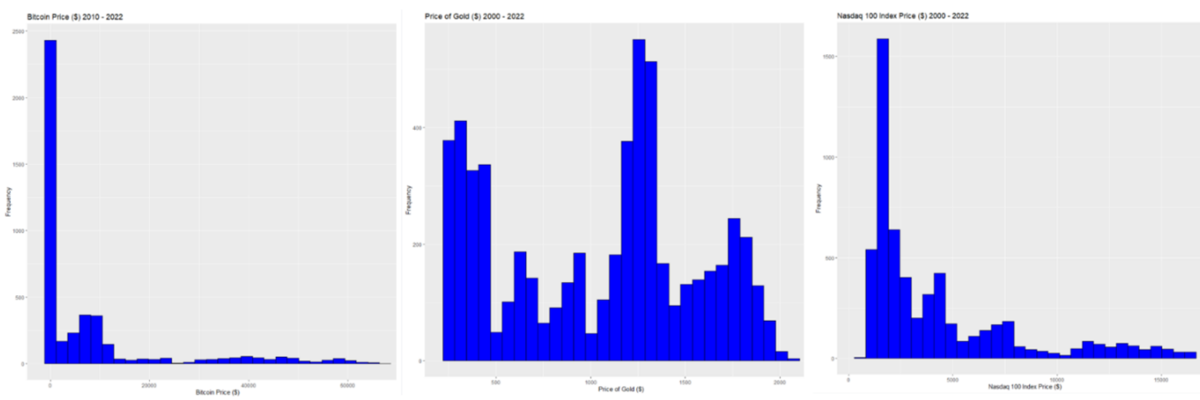

Figure 5. Asset Price Histograms (BTC, Gold, NDX)

Figure 6. below shows the asset prices of BTC, gold and NDX over time in the form of a line graph. The line graph shows that the BTC price spikes in 2013, this spike denotes an increase of 649% from Q3 to Q4, with BTC price rising from ~138 USD to ~1,033 USD. The next sharp spike identified is in 2017 where I can see BTC increase from ~960 in January to ~15,000 USD in December, before decreasing to ~4,000 USD in December 2018, with the BTC recovering to ~13,000 USD in June 2019. The line graph shows two distinct peaks that come in April 2021 with a BTC price of ~63,700 before a 50% decline in price before peaking with max value of 67,528 in November 2021. The decline from the highest value to date was significant, with the BTC price ~20,000 USD at the time of this study.

In contrast, we do not see the same levels of volatility when we look at gold and NDX. Gold shows a clear upward trend from 2000 to 2010 with a dip in prices around 2008, which coincides with the time of the 'Great Recession' (2007 – 2009). Prices then sharply increase from around 2010 – 2012 before prices return to the pre spike level between 2013 and 2015. There is another clear spike around 2020 where gold price hit the highest level in August 2020 (2,076 USD), before we see volatility when gold prices drop to around 1,700 USD in Q1 2021 before rising back to ~2,000 USD in Q1 2022 and then again dropping to 1,700 USD in Q3 2022.

NDX index price shows a downward trend from 2000-2010, before making a recovery to circa 2000 price levels in 2016. There is also a noticeable decrease in NDX index price between 2007-2009, a similar pattern we observed in the price of gold during the same period, which as mentioned, coincides with the 'Great Recession'. The NDX index price then surges between 2010 and 2020, with the exception of two noticeable dips around 2018 and the start of 2020. After the very sharp, but brief, drop in values at the start of 2020, I observed a very drastic increase in prices between 2020-2021, before the highest price recorded in November 2021. November 2021 was the same time that BTC's highest recorded price, which suggests to me that financial markets were thriving at this time, whereas gold prices had dropped 10% from their record high price recorded in August the previous year. This is an early suggestion that BTC price properties behave more similarly to an equity (index) than that of a commodity. It is worth noting that NDX prices, much like BTC and Gold prices fell throughout 2022, with moments of brief increases/recovery.

It is interesting, and worth highlighting that all three assets observed surging prices in 2020 around the same time as the onset of COVID-19 and also recorded their highest prices post COVID-19 onset.

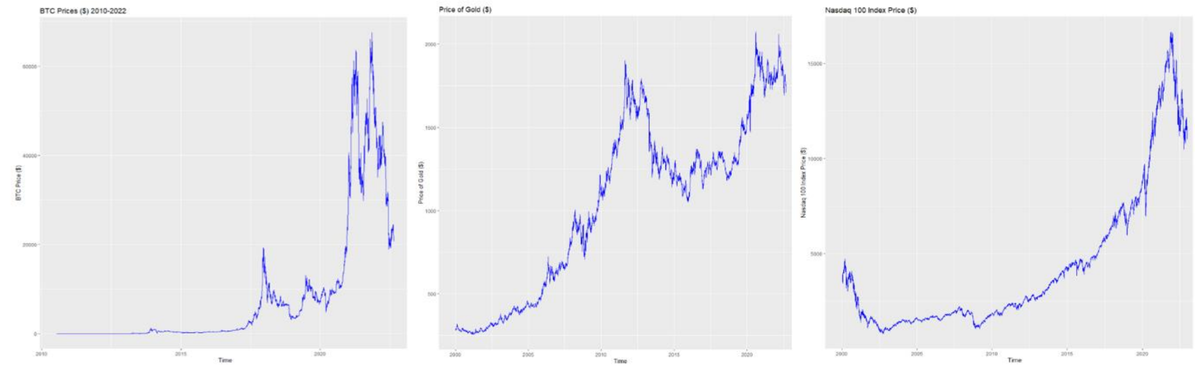

Figure 6. Asset Price Line Graph (BTC, Gold, NDX)

Fisher (1930) stated that inflation-hedging can be determined by looking at relationship between asset returns and inflation. Therefore, I now look at US macroeconomic data in order begin to answer my research question and build on the literature I have reviewed. I have explained in my methodology that I will be focusing on the inflation, consumer price index (CPI) and GDP variables from the dataset as per the research from Arnold and Auer (2015).

I begin my cleaning, exploration, and visualisation of the macroeconomic data by reading the dataset into R and used the head function to show data frame variables (columns) as shown in Figure 7. and establish the variables required for my analysis. In addition, the unemployment, mortgage interest rates and corporate bond yield will help my analysis my considering the impact of monetary policy shock and/or changes on the price of BTC as per the literature reviewed by Ma et al (2002) and Corbet (2017), who state that monetary policy shocks and interest rates positively impact BTC prices.

```
> #MacroEconomicData
> head(Data2, 10)
# A tibble: 10 x 15
   DATE                `UNRATE(%)` `CONSUMER CONF INDEX` `PPI-CONST MAT.` CPIALLITEMS `INFLATION(%)` `MORTGAGE INT. MONTHLY AVG(%)` `MED HOUSEHOLD INCOME` `CORP. BOND YIELD(%)` `MONTHLY HOME SUPPLY` `% SHARE OF WORKING POPULATION` GDP PE~1 QUART~2 QUART~3 CSUSH~4
   <dttm>                    <dbl>                 <dbl>            <dbl>       <dbl>          <dbl>                          <dbl>                  <dbl>                 <dbl>                 <dbl>                           <dbl>    <dbl>   <dbl>   <dbl>   <dbl>
 1 2022-05-01 00:00:00         3.6                  106.             353.        123.           8.58                           5.23                     NA                  4.13                   8.4                              NA    74737  19699.  -0.144    121.
 2 2022-04-01 00:00:00         3.6                  107.             344.        122.           8.26                           4.98                     NA                  3.76                   8.4                              NA    74737  19699.  -0.144    122.
 3 2022-03-01 00:00:00         3.6                  107.             346.        121.           8.54                           4.17                     NA                  3.43                   7                                NA    73289  19728.  -0.396    123.
 4 2022-02-01 00:00:00         3.8                  110.             344.        120.           7.87                           3.76                     NA                  3.25                   6                                NA    73289  19728.  -0.396    124.
 5 2022-01-01 00:00:00         4                    114.             346.        119.           7.48                           3.44                     NA                  2.93                   5.7                              NA    73289  19728.  -0.396    125.
 6 2021-12-01 00:00:00         3.9                  116.             335.        118.           7.04                           3.10                     NA                  2.65                   5.6                            64.9    72171  19806.   1.68     126.
 7 2021-11-01 00:00:00         4.2                  110.             329.        117.           6.81                           3.07                     NA                  2.62                   6.2                            64.9    72171  19806.   1.68     127.
 8 2021-10-01 00:00:00         4.6                  114.             322.        117.           6.22                           3.07                     NA                  2.68                   6.9                            64.9    72171  19806.   1.68     128.
 9 2021-09-01 00:00:00         4.7                  109.             317.        116.           5.39                           2.9                      NA                  2.53                   6.1                            64.9    69824  19479.   0.571    128.
10 2021-08-01 00:00:00         5.2                  114.             313.        115.           5.25                           2.84                     NA                  2.55                   6.5                            64.9    69824  19479.   0.571    129.
```

Figure 7. Macroeconomic Variables Dataset

After reading the data into R and dropping the variables I do not need for my analysis (identified in methodology), I have cleaned the data by changing the column names, as the existing column headings (variable names) are capitalised with spaces between the words, which is a format that does not work well when querying the data. Figure 8. below shows how my macroeconomic data looks once I have removed unwanted variables and renamed the variables.

```
> #rename columns from Marco Economic Data
> colnames(Data2)[1] ="Date"
> colnames(Data2)[2] ="Unemployment"
> colnames(Data2)[3] ="CPI"
> colnames(Data2)[4] ="Inflation"
> colnames(Data2)[5] ="Mortgage_Interest"
> colnames(Data2)[6] ="Corporate_Bond_Yield"
> colnames(Data2)[7] ="GDP_Per_Capita"
> head(Data2, 10)
# A tibble: 10 x 7
   Date                Unemployment   CPI Inflation Mortgage_Interest Corporate_Bond_Yield GDP_Per_Capita
   <dttm>                     <dbl> <dbl>     <dbl>             <dbl>                <dbl>          <dbl>
 1 2022-05-01 00:00:00          3.6  123.      8.58              5.23                 4.13          74737
 2 2022-04-01 00:00:00          3.6  122.      8.26              4.98                 3.76          74737
 3 2022-03-01 00:00:00          3.6  121.      8.54              4.17                 3.43          73289
 4 2022-02-01 00:00:00          3.8  120.      7.87              3.76                 3.25          73289
 5 2022-01-01 00:00:00          4    119.      7.48              3.44                 2.93          73289
 6 2021-12-01 00:00:00          3.9  118.      7.04              3.10                 2.65          72171
 7 2021-11-01 00:00:00          4.2  117.      6.81              3.07                 2.62          72171
 8 2021-10-01 00:00:00          4.6  117.      6.22              3.07                 2.68          72171
 9 2021-09-01 00:00:00          4.7  116.      5.39              2.9                  2.53          69824
10 2021-08-01 00:00:00          5.2  115.      5.25              2.84                 2.55          69824
```

Figure 8. Dropping and Renaming Macroeconomic Variables

Now I have cleansed the macroeconomic data, I will explore the data by looking at the central tendencies and measures of dispersion, as I did for the asset price data. The data looks evenly distributed for both CPI and inflation variables, with median and mean values that are similar in value. The larger difference between max and third quartile values than min and first quartile, suggests there may be high value outliers in the data, suggesting periods of high inflation. The target rate for the US fed is around 2% for inflation (Board of Governors of the Federal Reserve System, 2020). Sustained levels of high or low inflation, which is consistent with my findings in the data as the median inflation is 2%.

The US target rate for unemployment is around 4.5%, which is ~1% less than the median value, meaning that unemployment is trending higher than the target levels set out by the US government. The difference between the mean and the median values is only 0.5% which suggests to me that the data is evenly distributed around the mean. The significant difference between the third quartile value and the max value suggests there are outliers in the data i.e., a small number of periods of high unemployment.

Mortgage interest, corporate bond yield and GDP variables are evenly distributed with no outliers in the dataset. I will have a clearer idea how this looks when it comes to visualising the data.

```
> #MacroEconomicData
> summary(Data2)
      Date                      Unemployment         CPI            Inflation       Mortgage_Interest Corporate_Bond_Yield GDP_Per_Capita
 Min.   :2002-05-01 00:00:00   Min.   : 3.500   Min.   : 75.86   Min.   :-2.097   Min.   :2.684    Min.   :2.140    Min.   :37860
 1st Qu.:2007-05-01 00:00:00   1st Qu.: 4.700   1st Qu.: 87.72   1st Qu.: 1.464   1st Qu.:3.803    1st Qu.:3.690    1st Qu.:46977
 Median :2012-05-01 00:00:00   Median : 5.600   Median : 96.82   Median : 2.071   Median :4.457    Median :4.340    Median :51554
 Mean   :2012-05-01 10:09:27   Mean   : 6.075   Mean   : 95.54   Mean   : 2.296   Mean   :4.698    Mean   :4.471    Mean   :52896
 3rd Qu.:2017-05-01 00:00:00   3rd Qu.: 7.300   3rd Qu.:103.26   3rd Qu.: 2.970   3rd Qu.:5.812    3rd Qu.:5.410    3rd Qu.:58745
 Max.   :2022-05-01 00:00:00   Max.   :14.700   Max.   :123.32   Max.   : 8.582   Max.   :6.806    Max.   :6.750    Max.   :74737
```

Figure 9. Central Tendencies for Macroeconomic Variables

Figure 10. shows the measures of dispersion for the Macroeconomic variables. The standard error of the mean is a small number relative to the mean value for each of the variables, which suggests that samples are efficient, accurate and consistent. This is the same for the 95% confidence interval which suggests that there is low variability in the dataset variables. I am more focused on the coefficient of variation than the standard deviation as this shows me the ratio of the standard deviation in relation to its mean for each variable. This means that the coefficient of variation is a standardized and unitless measure that allows me to compare the volatility of the variables in the dataset. When comparing the inflation measure variables: CPI, inflation, and GDP, it is evident that inflation (%) is more volatile i.e., increases and decreases more sharply than CPI and GDP. Unemployment has a higher coefficient of variation that both CPI and GDP, which means that the level of unemployment reacts stronger to economic conditions than GDP and CPI. Both mortgage interest rates and corporate bond yield appear be equal in terms of volatility, which makes sense if both of these variables are impacted by monetary policy changes by the US government (Federal Reserve) by changing rates and increasing or decreasing money supply by buying and selling bonds, as per the Taylor Rule and Hofmann et al (2021).

```
> #MacroEconomicData
> stat.desc(Data2)
```

	Date	Unemployment	CPI	Inflation	Mortgage_Interest	Corporate_Bond_Yield	GDP_Per_Capita
nbr.val	241.0000000	241.0000000	241.0000000	241.0000000	241.00000000	241.00000000	241.0000000
nbr.null	0.0000000	0.0000000	0.0000000	0.0000000	0.00000000	0.00000000	0.0000000
nbr.na	0.0000000	0.0000000	0.0000000	0.0000000	0.00000000	0.00000000	0.0000000
min	1020211200.0000000	3.5000000	75.8595375	-2.0971614	2.68400000	2.14000000	37860.0000000
max	1651363200.0000000	14.7000000	123.3227996	8.5815115	6.80600000	6.75000000	74737.0000000
range	631152000.0000000	11.2000000	47.4632621	10.6786728	4.12200000	4.61000000	36877.0000000
sum	321943939200.0000000	1464.0000000	23025.0593835	553.4558943	1132.20750000	1077.55000000	12747956.0000000
median	1335830400.0000000	5.6000000	96.8192155	2.0705076	4.45750000	4.34000000	51554.0000000
mean	1335866967.6348548	6.0746888	95.5396655	2.2964975	4.69795643	4.47116183	52896.0829876
SE.mean	11809900.9910741	0.1279976	0.7141781	0.1057476	0.07213589	0.06950475	569.4726123
CI.mean.0.95	23264296.0328067	0.2521422	1.4068577	0.2083120	0.14210032	0.13691725	1121.8027522
var	33613176501972448.0000000	3.9483983	122.9221206	2.6949968	1.25406435	1.16424948	78156072.5264177
std.dev	183338966.1309686	1.9870577	11.0870249	1.6416446	1.11985014	1.07900393	8840.5923176
coef.var	0.1372434	0.3271044	0.1160463	0.7148471	0.23836963	0.24132518	0.1671313

m

Figure 10. Measures of Dispersion for Macroeconomic Variables

Figure 11. below shows the frequency distribution for the macroeconomic variables, in the form of a histogram. As identified through my data exploration, the inflation data were evenly distributed with some high value outliers/low frequency high inflation rate data, which is represented by the Inflation histogram (top left, Figure 11), which is clearly unimodal. Similarly, the GDP histogram (top right, Figure 11) is also unimodal, with evenly distributed data and higher value outliers. The CPI histogram (top middle, Figure 11) is bimodal, meaning there are two distinct peaks as appose to unimodal data such as both the inflation and GDP data. This is the same for both corporate bond yield and mortgage interest (bottom middle and right respectively), there is two noticeably clear peaks within the histograms. These two peaks for both corporate bond yield and mortgage interest could well indicate the response to monetary policy changes. The unemployment histogram (bottom left, Figure 11) shows positively skewed data with data clustered around the left tail, which suggests unemployment is frequently a lower value. There appear to be three 'bins' greater than 11% with low frequencies, which indicates there were three periods of high unemployment.

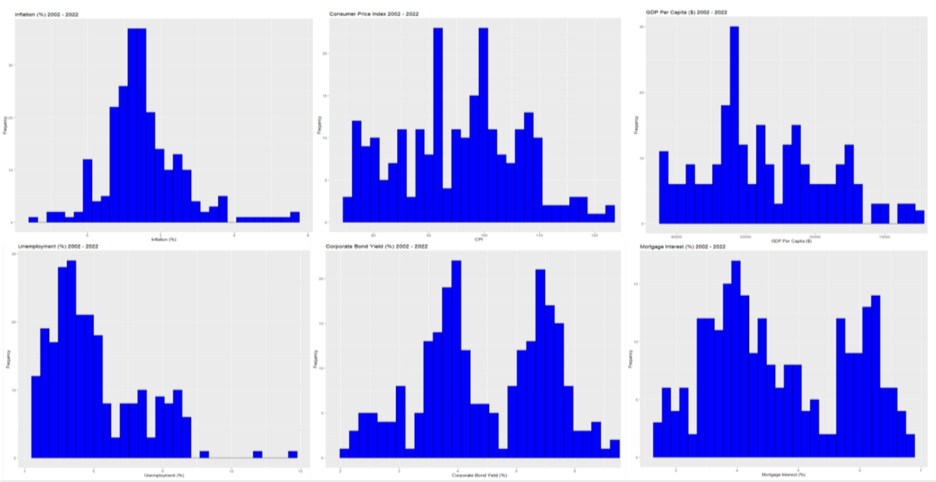

Figure 11. Macroeconomic Variables Histograms

The inflation variables: inflation, CPI and GDP line graphs below in Figure 12. show the respective values over time from 2002-2022. I have identified that CPI and GDP show a very similar trend over this 20-year period. They both show continuous growth through the timeseries, with notable dips around the same time as the 'Great Recession' from 2009. This is also shown on the inflation line graph, whereby I observed negative inflation during this period. CPI and GDP both show steady and continuous increases post the great recession before there is another what appears to be another sizeable economic event in 2020. Inflation, CPI and GDP all show a significant drop in values at the start of 2020, before a very sharp increase that continues through to 2022. These sharp increases suggest that the economy was overheating between 2020 and 2022, with inflation levels well above the Feds 2% inflation target rate, which coincides with the onset of COVID-19, which commenced in Q1 2020. One of the very interesting points that I notice from the inflation variables is that inflation, CPI and GDP all continue to rise throughout the period post the onset of COVID-19 (Q1 2020), whilst BTC, gold and NDX prices all decline through 2022, with BTC and NDX suffering larger decreases, inflation is increasing, which is of course a sign that BTC did not successfully hedge against inflation in 2022. This adds weight to Conlon et al (2021) argument that there is only a brief positive relationship between the price of BTC and forward inflation rates, which coincides with the initial stages of COVID-19.

The unemployment trend is consistent with economic theory (Okun's Law), in as much that drops in inflation related variables coincide with increases in unemployment levels, as with higher unemployment comes a reduced economic efficiency and output. During the 'Great Recession' period of 2007-2009, I have already highlighted that inflation, CPI and GDP variables decreased, whilst observing increased levels of unemployment. The same is observed during the 2020-2022 period, of course coinciding with the COVID-19 onset. The decreases of inflation, CPI, and GDP in early 2020 occurs at the same time as unemployment spikes from the unemployment target rate of 4.5% to 14.7%, which is ~5% higher than the unemployment post the 'Great Recession' in 2010.

Both mortgage interest rates and corporate bond yield are responses to monetary policy changes as per the Taylor rule. Monetary policy changes will occur when the government need to intervene to either slow down or encourage growth in the economy. From Figure 12. I observed that the economic theory is consistent with the data, as inflation related variables drop around 2008, we can see reductions in both the mortgage interest rates and corporate bond yield around the same times, which suggests that the US government decreased interest rates and increased money supply in reaction to cooling economy. However, this trend is much more interesting in 2020-2022 during the COVID-19 period as we observe a sharp fall and an even sharper increase in inflation, which triggers the same pattern for the corporate bond yield and mortgage interest variables.

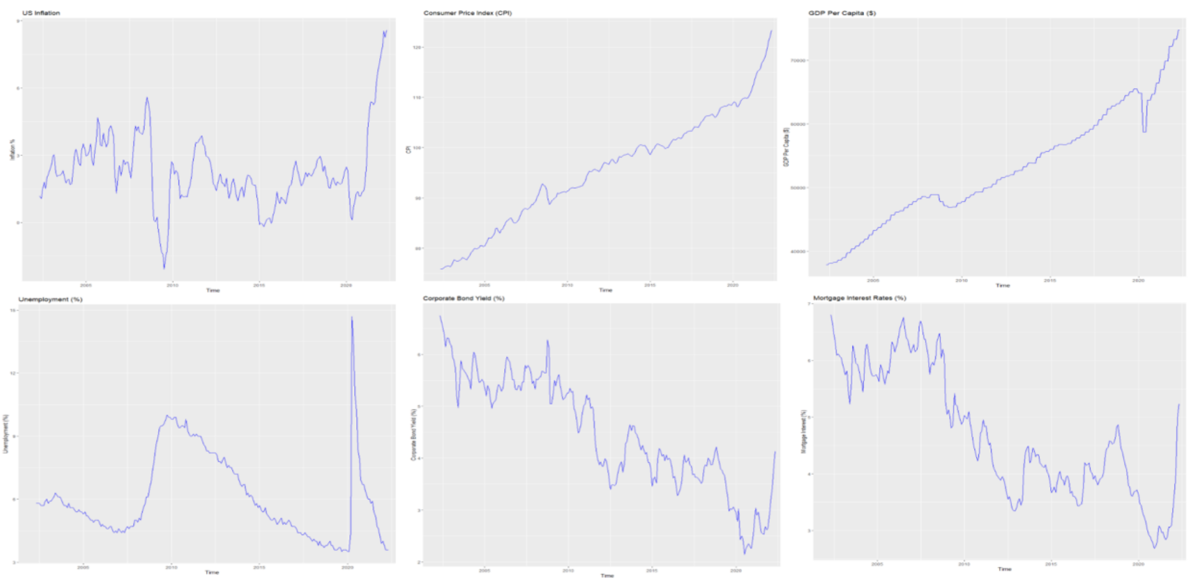

Figure 12. Macroeconomic Variables Line Graph

4.2. Correlation Analysis

I have analysed the relationship between BTC, Gold and NDX prices by looking at how their respective prices change over the time and looking at the patterns and trends in the data in the form of data visualisation and measures of dispersion. This has highlighted that BTC prices are more volatile than that of gold and NDX prices. Therefore, it is essential for me to look at the correlation between these asset prices, as the degree of correlation will give me a clear idea of the relationship between these variables.

Figure 13. shows a strong positive correlation between BTC (open) and NDX (Nasdaq100), with a correlation of 90%. This suggests that as BTC prices increase, NDX prices also increase and vice versa. BTC (open) and gold also have a strong positive correlation, with a correlation of 61%, which shows that the properties and behaviour of BTC are more similar to a stock market index than gold.

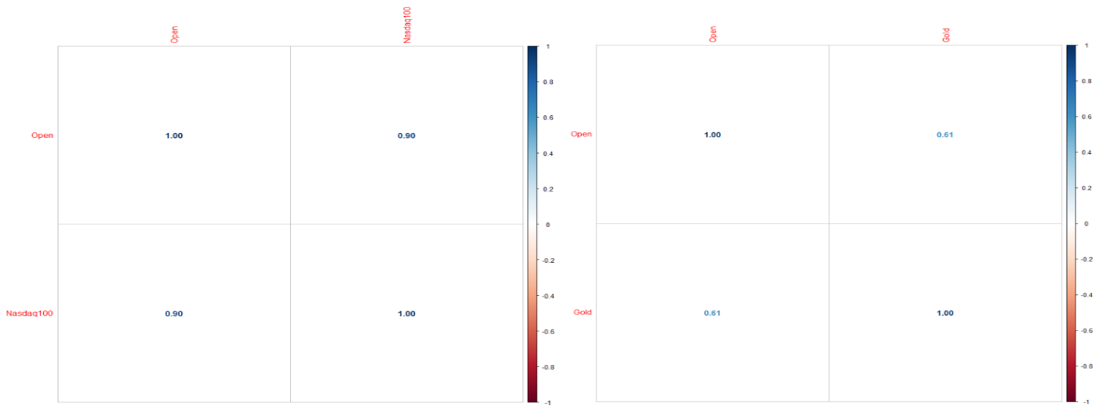

Figure 13. Asset Prices Correlation Matrix

The scatter plot in Figure 14 visually represents the relationship between BTC, gold and NDX prices. I can see here the linear relationship is clearer when looking at BTC and NDX prices. The gold price remains stable as soon as BTC prices are greater than 10,000 USD, which shows that the two variables move in the same direction, but BTC will have higher fluctuation levels, which is consistent with what we know about BTC financial risk (volatility).

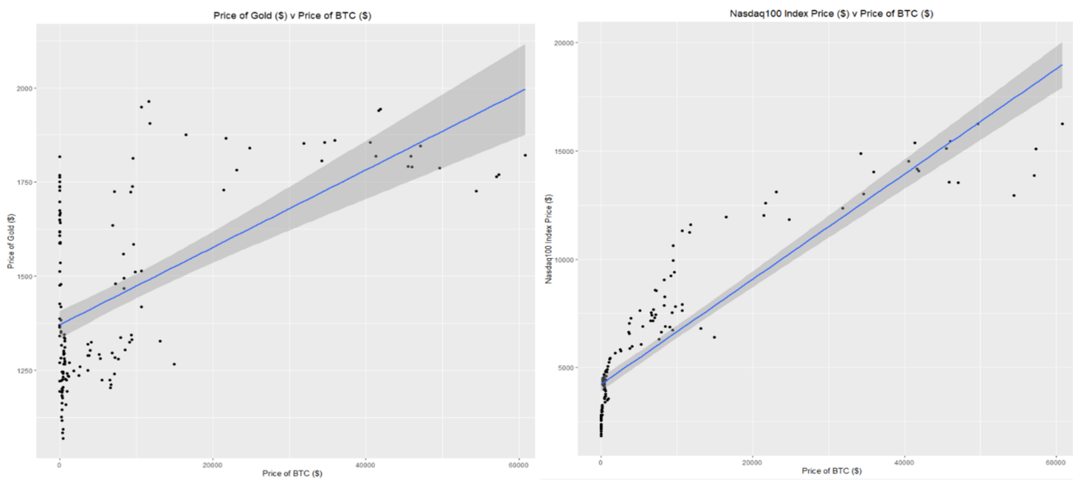

Figure 14. Asset Prices Scatter Plot

Brodie (1976) argued that an asset can be considered an inflation hedge if a positive correlation between the nominal return of the hedging asset and inflation. Therefore, I will perform correlation analysis between BTC and inflation variables to determine the validity of the findings from the literature. I will also compare the BTC/Inflation correlation against gold and NDX to determine if the correlation we are seeing is comparatively significant.

The below correlation matrices in Figure 15 show the correlation between the macroeconomic variables and BTC, gold and NDX prices. I will begin by looking at the BTC and macroeconomic variables correlation. BTC prices show an 81% correlation with CPI, 71% with inflation and 79% with GDP, thus allowing me to conclude that regardless of the inflation measure used, BTC price and inflation have a strong positive correlation. This gives me an early indication that BTC could be used to hedge against inflation, which in consistent with the findings of Ciaian et al (2016), Choi & Shin (2022) and Blau et al. (2021). The correlation matrix shows that BTC and Inflation variables both have a negative correlation with unemployment, mortgage interest rates and corporate bond yield, which indicates that monetary policy changes and thus market conditions impact BTC, which is consistent with the finding of Ma et al (2022) and Corbet (2017) that monetary policy changes have a strong reaction in terms of the BTC price.

The correlation analysis of gold prices vs macroeconomic variables told me that the price of gold has a strong relationship with both CPI and GDP, with a correlation of 89% and 81% respectively. NDX prices also show a strong positive correlation with CPI (87%) and GDP (91%), and a moderate correlation with inflation. Gold and NDX both show a strong negative correlation with mortgage interest and corporate bond yield, which explains that these assets are impacted by monetary policy changes.

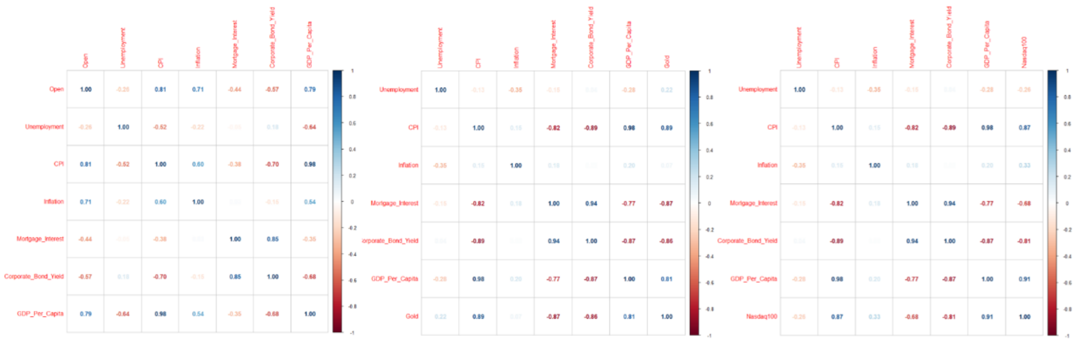

Figure 15. Macroeconomic Variables Line Graphs

As identified from the correlation analysis and from the below scatter plots in Figure 16, I can see that BTC has inflation-hedging properties in the sense that there is a strong positive relationship between asset price and CPI. Therefore, by looking at correlation, I can begin to understand that there may be inflation-hedging properties for BTC as per Brodie (1976) definition of inflation hedging, whereby an asset can be considered an inflation hedge if a positive correlation between the nominal return of the hedging asset and inflation. However, when comparing BTC price and CPI relationship against that of my benchmark assets gold and NDX, I know that the correlation with CPI for BTC is weaker than both gold and NDX prices and does not show as smooth a linear relationship as NDX and gold vs CPI.

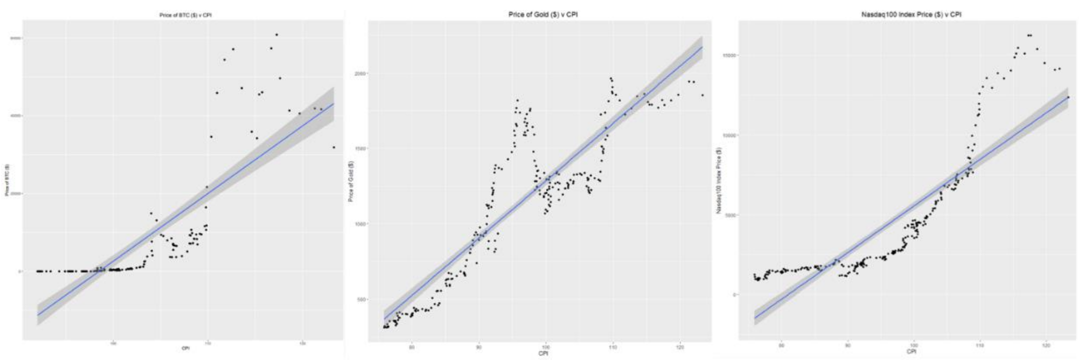

Figure 16. Asset Prices vs CPI Scatter Plot

4.3. Volatility Analysis

I found from my literature that the scholars who look at the BTC's inflation-hedging properties (Ciaian et al (2016), Choi & Shin (2022), Blau et al (2021), Conlon et al (2021)) do not look in depth at the high associated volatility of BTC when determining the inflation-hedging properties of BTC. This is important analysis as Bodie (1976) states that one way to define inflation-hedging is as asset reduces variance or uncertainty, which would not be the case if we are dealing with a highly volatile asset. I found that Dyhrberg (2016) and Gronwald (2019) studies uses a GARCH model to determine correlations in the financial risk/volatility of assets, which allowed for identification of shared properties between the assets.

Therefore, I have applied GARCH model to measure the financial risk of BTC and compare this against the financial risk of gold and NDX. The level of financial risk that is associated with an asset must be considered and compared against a benchmark/alternative inflation-hedging asset when determining its inflation-hedging properties as Bodie (1976) states that one way to define inflation-hedging is if an asset reduces variance or uncertainty, which would not be the case if we are dealing with a highly volatile asset. I referenced literature from Gronwald (2019) and Dyhrberg (2016) in both my literature review and methodology and found that a GARCH model was implemented as part of this research to identify volatility correlations between different assets.

4.3.1. Volatility Clustering

The first step I have deployed to establish the volatility of my asset returns is through the use of volatility clustering to reflect the daily percentage changes in the asset prices. Figure 17 below shows the volatility clustering plot for BTC, gold, and NDX, which will give me an overview of the volatility associated with each of the assets. I can see from the volatility clustering graphs in Figure 17 that BTC is a more volatile asset than both gold and NDX, and NDX prices appear to be slightly more volatile than gold prices, with higher price fluctuations. There are siginificantly more 'spikes' in the BTC plot than both gold and NDX, also the level of BTC returns volatility in terms of percentage change is much more significant.

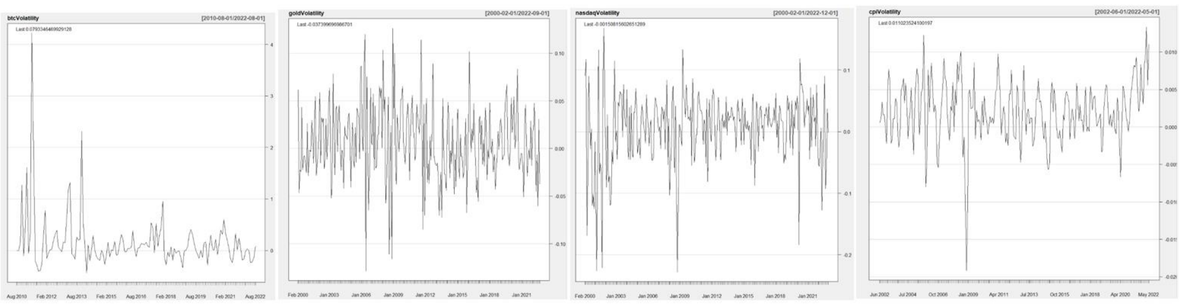

Figure 17. Volatility Clustering

4.3.2. Dynamic Conditional Correlation (DCC) GARCH

I have modelled the volatility of a vector of assets (BTC, gold, NDX and CPI) using DCC-GARCH to find the time varying correlation between the returns of BTC, gold, NDX and the changes in CPI as a function of their past volatility and the correlations among them. This will allow me to see how BTC performance volatility correlates with gold and NDX returns and compare the volatility of BTC and CPI.

Figure 18 below show the time varying volatility correlations between BTC, gold and NDX prices, this will help me determine how BTC prices compare to the benchmark assets in terms of the volatility of prices. My analysis tells me that BTC returns have a negative correlation with gold returns, which tells me that BTC and gold inflation-hedging properties are significantly different as per Figure 18. From the GARCH correlation matrix I found that over the time series BTC returns and gold returns trend around -13.32% correlation. BTC and NDX returns are positively correlated, with correlation trending around 19% over the time series, which tells me that the inflation-hedging properties of BTC are more similar to NDX than gold.

Figure 18. Time Varying Correlation (BTC, Gold, NDX)

Figure 19 shows the time varying volatility correlations between BTC, gold, NDX prices and CPI. I also found that BTC price movements and CPI changes are positively correlated (trending around 2.5%), but due to the low correlation, this suggests there is no significant relationship as per Figure 19. Gold price movements and CPI changes trend around 19% correlation, which shows a positive relationship between the two variables. NDX and CPI show a small positive correlation, with correlation trending around 8% throughout the time series

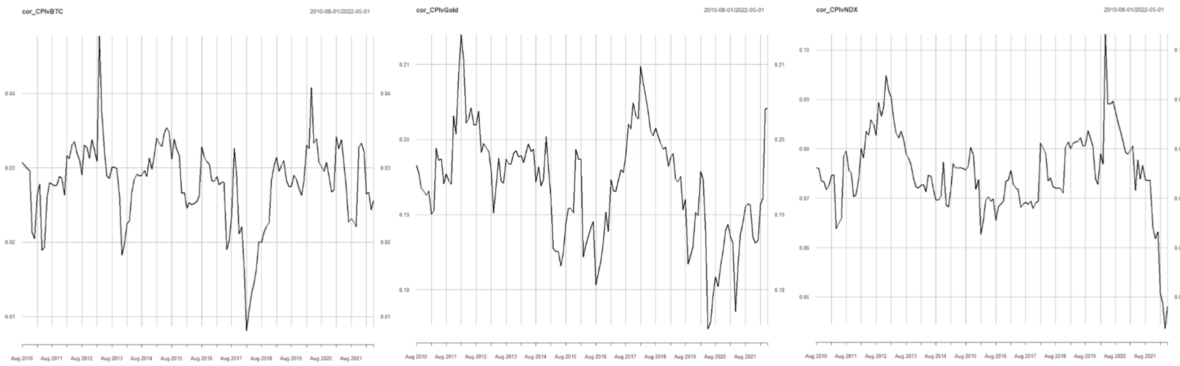

Figure 19. Time Varying Correlation (CPI vs. BTC, Gold and NDX)

5. Model Implementation

I have focused on explanatory data analysis, correlation analysis and volatility analysis in chapter 4 to understand the inflation-hedging properties of BTC. In chapter 5, as discussed in my methodology, I will establish if BTC is an effective inflation-hedge by adopting Vector Autoregressive (VAR) models. VAR is a statistical model that will allow me to look at the relationship between BTC and CPI variables relationship over time. This time series model relates the current and past observations of a variable with the other variable, i.e., the VAR model will enable feedback between the BTC and CPI variables in the model using their current and lagged values. In order to analyse the results of the VAR model using including the BTC and CPI variables, I am also going to build two other models to look at the relationship between gold and NDX prices returns vs CPI, which are my benchmark assets.

5.1. Building VAR Model

Before building my VAR model in R, I have used the Augmented Dickey-Fuller (ADF) test to determine if the variables I am looking at are stationary or non-stationary and found that BTC price, CPI, gold price and NDX price variables have p-values of 0.51, 0.99, 0.63 and 0.43, respectively. The alterative hypothesis is stationary data, and as the p values are all greater than 0.05, I am unable to reject the null hypothesis, thus the time series data is non-stationary for all the variables tested.

I have combined the diff() and log() functions in R to find the log difference, which shows the continuously compounded and exponential growth rate, which has symmetry and bounding advantages when compared to period-on-period growth rates. The log difference will first take the logs to get a series with a liner trend and then the difference of the log series will reflect a stationary time series. I applied to log difference to the BTC, gold and NDX price variables as well as the CPI variable. I have three different CPI variables as the time series period is different for BTC, gold and NDX, with BTC data starting in 2010 and gold and NDX data starting in 2000. Therefore, the BTC and CPI relationship analysed will run from 2010-2022, whereas gold and NDX relationship with CPI will be analysed from 2002-2022 (CPI data runs from 2002-2022).

After running the log difference on each of the variables, I re-ran the ADF test and found that all variables are now stationary data, with p scores less than 0.01. I have plotted the log difference data, as shown in Figure 19 below, it is clear from these plots that the data is now stationary as the mean and variance do not vary across time.

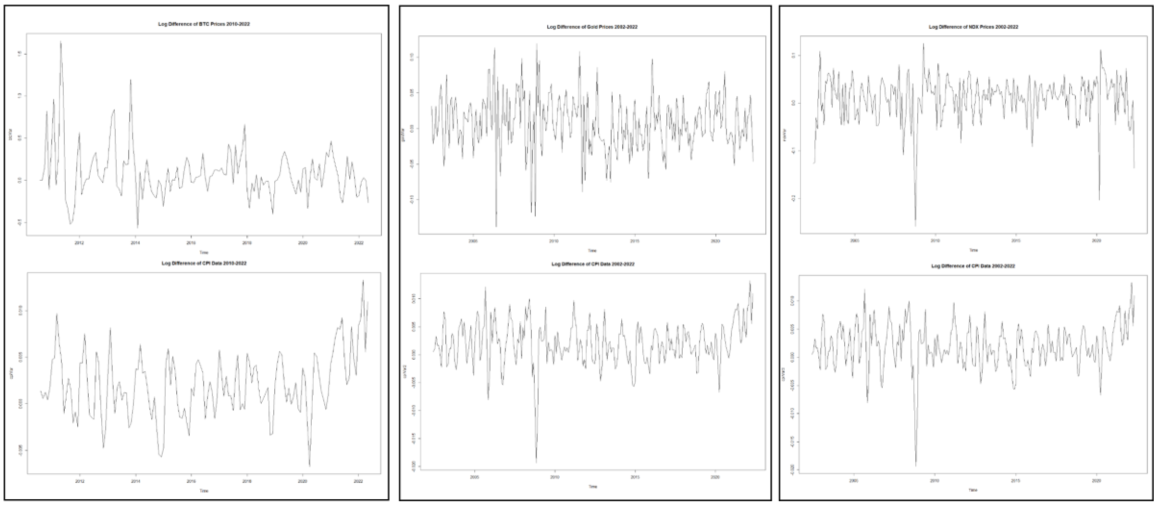

Figure 19. Stationary Data Plots

Now I have converted my time series data from non-stationary to stationary, I am going to begin to build my VAR models, and the first step is to find the optimal lags for each model. I used the "VARselect" function in R which is used to return information criteria and final prediction error for sequential increasing the lag order up to a VAR(p)-process. which are based on the same sample size as per R documentation. It is important for me to find the optimal number of lags and apply this when building my model to reduced residual correlation.

I have used R to bind together variables as follow; BTC & CPI to create model1, Gold & CPI to create model 2 and NDX & CPI to create model 3 and used the VARselect function to find the number of optimal lags for each of these models. I found that the optimal lags is 2 for each of these models.

5.2. Diagnosing VAR Model

I need to diagnose and check for robustness in a VAR model by evaluating each model for serial correlation, heteroscedasticity, and stability. The first test I performed on the models is the Portmanteau test, which is the serial.test function in R. The purpose of this test is to establish if there is serial correlation associated with my models. Serial correlation will cause an issue for my VAR models as the model assumes that errors are independent, however, if serial correlation is present, each error depends on previous residuals i.e., an error is correlated with errors in previous periods. I found from my testing that all three models have p-values greater than 0.05, this I can conclude that there is no serial correlation associated with my models.

The next test I performed on my model is the arch.test in R, which checks for heteroscedasticity in the model. The p-value is less than 0.05 for each of my models, thus allowing me to identify that there is heteroscedasticity present in each of the models. This means that data used in the VAR model contains unequal variance and implies that the results from the VAR model may be invalid.

The final test performed on my models was for structural breaks, which can be seen graphically plotted in Figure 1.41. The Ordinary Least Square Cumulative Sum (OLS-CUSUM) tests for structural changes in the model. The red lines on the graph (Figure 20) show the boundaries, and I can see that these boundries are exceeded for both cpiVar and goldVar, meaning there is evidence of a structural change at this point in time for these variables. The structural breaks are very brief and only exceed the boundary slightly in both cases, thus I will continue with the models. There are no structural breaks for btcVar (BTC variable for model 1), ndxVar (NDX variable for model 3), or cpiVar 2 and cpiVar 3 (CPI variable for models 2 and 3 respectively).

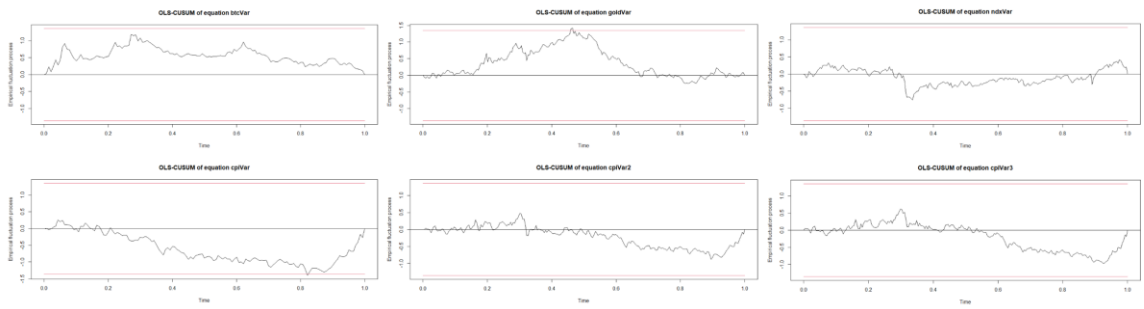

Figure 20. Structural Breaks

5.3. VAR Model Results

I have built my VAR model and tested its robustness and stability; therefore, I am now going to look at the VAR model results in terms of the relationship between the variables over the period of the multivariate time series. I will look at the granger causality, impulse response function and the variance decomposition to help me establish the effectiveness of BTC as an inflation-hedge relative to that of gold and NDX.

Granger causaility is a test used to establish if a variable is useful in terms of forecasting another variable. Damos (2016) states that Granger causality provides a more stringent criteron for causation, or information flow, than simply observing high correlation with some lag-lead relationship. Therfore, I can compare the results for BTC and CPI against my benchmark assets, gold and NDX. The null hypothesis for the granger causality test is that variable 1 does not Granger-cause variable 2, therefore, if the p-value is significant (less than 0.05), I can reject the null-hypotheses, and conclude that a variable is useful in forecasting another variable. Figure 21 shows the granger causailty results for BTC/CPI (left), Gold/CPI (middle) and NDX/CPI (right), and tells me that:

- BTC does **not** Granger-cause CPI, and CPI does **not** Granger-cause BTC.
- Gold does **not** Granger-cause CPI, however, CPI **does** Granger-cause Gold.
- NDX **does** Granger-cause CPI, whereas CPI does **not** Granger-cause NDX.

```
> grangerbtccpi <- causality(model1, cause = "btcVar")
> grangerbtccpi$Granger

        Granger causality H0: btcVar do not Granger-cause cpiVar

data:  VAR object model1
F-Test = 1.351, df1 = 2, df2 = 270, p-value = 0.2607

> grangercpibtc <- causality(model1, cause = "cpiVar")
> grangercpibtc$Granger

        Granger causality H0: cpiVar do not Granger-cause btcVar

data:  VAR object model1
F-Test = 0.18893, df1 = 2, df2 = 270, p-value = 0.828
```

```
> grangergoldcpi <- causality(model2, cause = "goldVar")
> grangergoldcpi$Granger

        Granger causality H0: goldVar do not Granger-cause cpiVar2

data:  VAR object model2
F-Test = 0.12793, df1 = 2, df2 = 466, p-value = 0.8799

> grangercpigold <- causality(model2, cause = "cpiVar2")
> grangercpigold$Granger

        Granger causality H0: cpiVar2 do not Granger-cause goldVar

data:  VAR object model2
F-Test = 5.1907, df1 = 2, df2 = 466, p-value = 0.005895
```

```
> grangerndxcpi <- causality(model3, cause = "ndxVar")
> grangerndxcpi$Granger

        Granger causality H0: ndxVar do not Granger-cause cpiVar3

data:  VAR object model3
F-Test = 3.7519, df1 = 2, df2 = 466, p-value = 0.02418

> grangercpindx <- causality(model3, cause = "cpiVar3")
> grangercpindx$Granger

        Granger causality H0: cpiVar3 do not Granger-cause ndxVar

data:  VAR object model3
F-Test = 0.30018, df1 = 2, df2 = 466, p-value = 0.7408
```

Figure 21. Granger Causality Test

The impulse response function (IRF) looks at the impact of one variable as a result of a shock to another variable, thus in my case I can predict implications of shocks to CPI on BTC, gold and NDX prices. The results for BTC response to CPI shocks can be compared with the results of gold and NDX response to CPI shocks. This will enable me to establish how BTC compares to benchmark assets when determining how effectively BTC can hedge against inflation. Figure 22 shows the impulse response forecast plots for the next 12 period (12 months), the top row shows the three assets response to CPI shocks, and the bottom row shows the the CPI response to shocks to the asset prices. The solid line on the graph represents the movement of the asset that is responding to the shock and the dotted line is the 95% confidence interval.

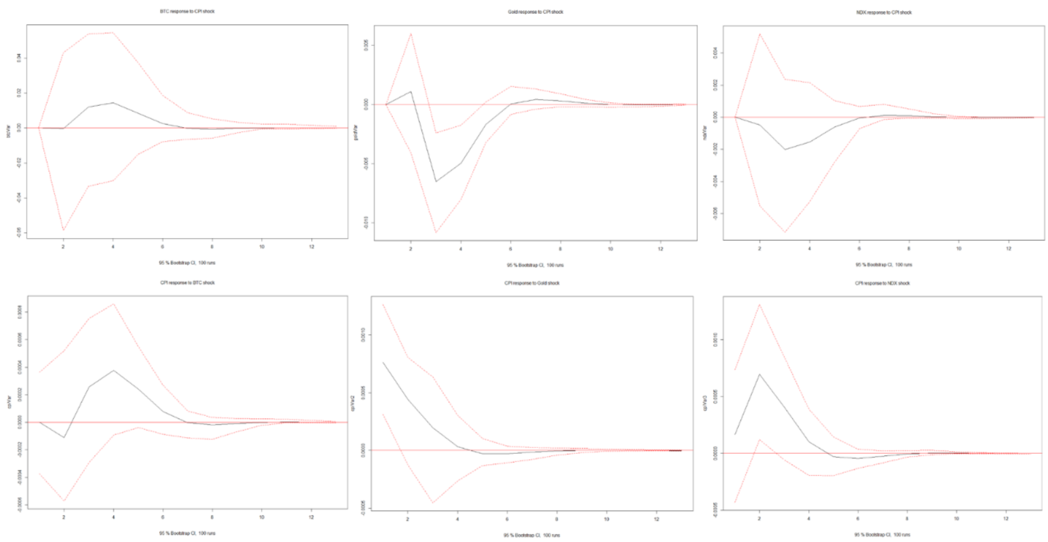

Figure 22. Impulse Response Function

it is imperitive to look at the variance decomposition as part of the structural analysis by using the forecast error variance decompisition (FEVD) in R. This allows me to see how important a shock is in explaining the variations of each of the variables in my models. Variance decompistion will shows me the importance of a shock over time, and whether the shock is responsible for long or short run variations. The forecast error variance decomposition is based upon the orthogonalised impulse response coefficient, which was looked at above as part of the IRF test. Figure 23 shows the FEVD function output from R where I have used 12 periods look-ahead for my forecast. Oejfopij

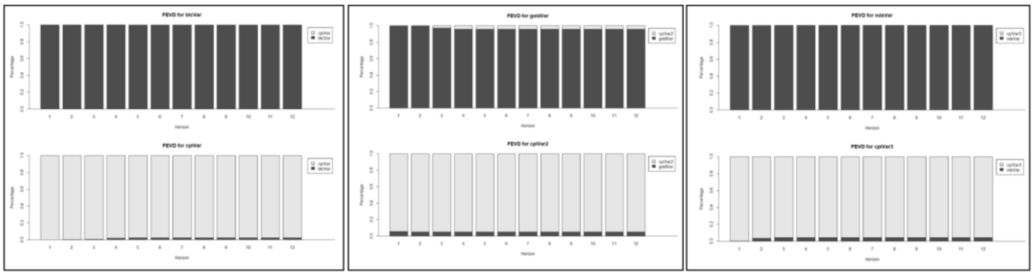

Figure 23. Impulse Response Function

6. Discussion of Results

I will first evaluate the results of my exploratory data analysis on BTC, gold and NDX daily price data. I found from looking at the measures of dispersion data that the coefficient of variation for BTC daily price data is significantly higher than both gold and NDX daily prices, meaning the BTC price data is more dispersed from the mean value. The coefficient of variation is the standard deviation relative the mean, which I another way of measuring the financial risk or volatility of an asset. Therefore, from the measures of dispersion data I know that BTC can be considered more volatile than both gold and NDX and could be evidence that the inflation-hedging properties of BTC may not be as strong as gold or NDX. I find these results meaningful as Bodie (1976) states that one way to define inflation-hedging is if an asset reduces variance or uncertainty, which would not be the case if we are dealing with a highly volatile asset. This is addressing the weakness I noticed from my literature that the scholars that look at BTC as an inflation-hedge, do not consider the level of volatility associated with BTC.

In terms of the visualisation of data, this is important in helping me determine the inflation-hedging properties of BTC by implementing the theoretical concept of Fisher (1930) and examine the relationship between BTC and inflation over time. I can see from the asset prices over time (Figure 6) that BTC prices are more volatile than gold and NDX, which is consistent with my findings when looking at the measures of dispersion. The more meaningful analysis comes when I compare the BTC asset prices to the macroeconomic data plots in Figure 12, as this allows me to directly compare BTC price changes against inflation changes. I can see that the CPI has increased throughout the time series, with periods of decreases, but overall, there is a very steady increase over time. However, from my observations on the BTC price data, I see far more peaks and troughs, with periods that would most certainly not hedge against inflation. I found that CPI, inflation, and GDP have sharply increased since the onset of COVID-19, whereas BTC prices have been very volatile with a sharp increase and record high prices in November 2021 of $67,528, followed by a decline of ~30% in price my mid-2022. Without undertaking any further test and simply looking at the data visualisations, I struggle to find the inflation hedging properties when applying Bodie (1976) definitions of inflation-hedges as I do not see any evidence that the return of BTC is greater than or equal the rate of inflation or the asset reduces variance or uncertainty caused inflation. From the literature reviewed, Blau et al (2021) findings are that there is a positive relationship between BTC prices and inflation and reject that the onset of COVID-19 caused this positive relationship. Whereas Conlon et al (2021) argue that the pandemic was the cause of the 'brief' positive relationship between BTC prices and inflation. I can see that elements of validity in Conlon et al (2021) argument as I do not see significant inflation-hedging properties prior to the onset of COVID-19.

When it comes looking at the relationship between BTC prices and inflation since the onset of COVID-19, I can look at the literature from Ma et al (2022), who's research found that monetary policy shocks result in strong positive reactions (positive relationship). I can see from Figures 6 & 12 that despite rising inflation 2022, interest rates and corporate bond yield are also rising throughout the same period. This tells me that despite increasing interest rates and reduced money supply (higher corporate bond yield), inflation levels have still not come down. Therefore, BTC is not hedging against inflation post the onset of COVID-19, but BTC prices have seemingly reacted strongly to monetary policy shocks. I have identified there is a monetary policy shock or 'monetary stimulus' during this period as Conlon et al (2021) state that as a result of the COVID-19 crisis, many countries has begun to implement 'aggressive' monetary stimulus to support the economies, which corroborates with the macroeconomic data (rising interest rates and bond yield). This also proves that Corbet (2022) research on BTC prices being influenced by interest rates adjustments appears to be valid post COVID-19. This ultimately leaves questions around whether BTC is really shielded from government interference, as proposed by Osterrieder et al (2016), who also gives this as the reason why BTC can be considered an inflation-hedge.

The correlation analysis in Figure 15 found a strong positive correlation between BTC prices and inflation, CPI and GDP which is one method to determine if an asset can be considered an inflation-hedge, as per Bodie (1976). Bodie (1976) states that an asset has inflation-hedging properties if the asset return and inflation are positively correlated, which I found to be true as BTC is 81% correlation with CPI, 71% with inflation and 79% with GDP. I also found from my correlation analysis that BTC prices are 90% correlated with NDX prices and 61% with gold prices, as shown in Figure 13, which leads to believe that due to the strong correlation between these assets that BTC could share the inflation-hedging properties of these assets. I found from the correlation analysis and the scatter plot in Figure 14 that the relationship between BTC and NDX is more similar than that of BTC and gold and there is far more literature in support of gold as the traditional inflation-hedge. Baur and McDermott (2010) argue that investors have traditionally used gold as a hedge against inflation or a falling dollar and Ivanov (2017) found that gold is a partial hedge, and stocks do not hedge against inflation.

In regard to the statistical models used to determine the inflation-hedging properties of BTC, I found from my DCC-GARCH model that BTC price returns are negatively correlated with gold price returns throughout the time series data, with time varying correlation trending around -13%, which implies that BTC does not replace Gold as an inflation-hedging asset. I would expect to see a strong price returns correlation between BTC and Gold if I were to conclude that BTC shares the inflation-hedging properties of gold. I found that BTC and NDX price returns were on average around 20% positively correlated over time, indicating that the assets are behaving in a similar way in terms of their price movements. However, from the volatility clustering plot in Figure 17, it is clear that despite BTC and NDX having positive returns time varying correlation, BTC is still far more volatile than NDX which contradicts Bodie (1976) characteristics definition of an inflation-hedge in the sense that BTC does not reduce variance or uncertainty caused by inflation. The BTC returns have a small positive time varying correlation with CPI, as per figure 19, however, the positive time varying correlation trends around 2-3%, which is so small that it is arguable insignificant and can be concluded that no relationship exists between BTC price returns and CPI changes. Whereas gold and CPI have a positive time varying correlation that is consistently between 18-20% over the time of the analysis. This is more evidence that BTC does not have the same ability to hedge against inflation that gold does. NDX also has a stronger time varying correlation with CPI than BTC, but weaker than gold. Overall, from my statistical modelling it’s clear that BTC is more volatile than gold and NDX and also has a significantly weaker time varying correlation with CPI than gold.

From the tests performed on my VAR models, I first looked at Granger-causality (Figure 21) and found that there is no causation from CPI changes to BTC prices or CPI changes to NDX prices, and that CPI is useful in forecasting gold price as there is causation between CPI and gold price, which is what I would expect to see for an asset that has inflation-hedging properties as defined by Baur and McDermott (2010), Ghosh et al. (2004) and Worthington and Pahlavani (2007), Panagiotidis (2015) and Ivanov (2017 . However, because I do not see causality from CPI to BTC or NDX, this is a clear indication that BTC and NDX prices are not driven by CPI changes i.e., BTC and NDX show no evidence of being able to hedge against an increase inflation. In the reverse direction, I found that gold and BTC prices do not cause changes in CPI, whereas NDX Granger-causes CPI, which tells me NDX price movements are useful to predict CPI change/movement. Therefore, when comparing the results of the Granger-causality tests on BTC against my benchmark assets, I can see that both gold and NDX show causation with CPI in different direction, which is more evidence of a lack of inflation-hedging properties for BTC in comparison to the benchmark assets. Granger-causality was not considered in the research of Choi & Shin, who concluded that BTC could be a useful hedge against inflation. However, I believe that had this step been taken in the analysis, Choi & Shin (2022) may have reached a different conclusion.

The IRF test results in Figure 22 show me that in terms of the size of the response, BTC reaches around 1.5% log difference increase as a response to the CPI shock, whereas gold only reaches a 0.1% increase and NDX decreases 0.2%. When looking at the confidence intervals, I can see that the BTC response to the CPI shocks lie between positive and negative 5% compared to positive 0.6% and negative 1% for gold and positive 0.5% and negative 0.7%. These results tell me that BTC is hedging against CPI shock more effectively than both gold and NDX.However, I am observing far wider range of forecasts for BTC prices than gold and NDX as shown by the confidence internal lines on the graph in Figure 1.43. In addition, the response to the shock is not neccesarily explained by the variable that is shocked, this could be explained by the response variables own past values.

The variance decomposition results in Figure 23 show that depsite the results from the IRF indicating that BTC is more effectively hedging against the inflation shock, this is 99% explained by it's own past values and not as a direct result of the CPI shock. In comparison to the variance decomposition results on the VAR model focusing on gold and CPI variables, I can see that the ~5% of the gold price varability is epxlained by CPI from periods 4-12, which shows that CPI shocks explain more of the variablity in gold price returns than for BTC. This is further evidence that gold is more effective when it comes to hedging against inflation than BTC. This also tells me that in time that BTC has sucesfully hedged against inflation, this was driven by itself (BTC) and not by inflationary changes, meaning there is no inflation-hedging properties asscoaited with the asset and that rising BTC prices coincided with inflationary developmeny by chance.

7. Conclusions, Limitations and Future Research

To conclude, I have applied Fisher (1930) theoretical concept of how to identify inflation-hedging properties by examining the relationship of the BTC and inflation over time and used Bodie (1976) characteristics of inflation-hedging properties below to determine if BTC can be considered an inflation hedge.

i. Return of BTC is greater than or equal the rate of inflation
ii. BTC reduces variance or uncertainty caused by inflation
iii. Inflation and BTC return are positively correlated

The volatility of BTC proves to be a big problem when it comes to determining if BTC is an inflation hedge. I found from the measures of dispersion (coefficient of variance and standard deviation), data visualisation of variables over time, volatility clustering and DCC-GARCH model that BTC is more volatile than both gold and NDX prices and CPI changes/movements. Therefore, as per Bodie (1976) definition of inflation-hedging properties, my research rejects the notion that BTC reduces variance or uncertainty caused by inflation. Bodie (1976) argues that an inflation-hedge can also be identified if the asset is positively correlated with the inflation, and despite a positive correlation between BTC and CPI, I found that both gold and NDX had a stronger positive correlation with CPI. Moreover, my DCC-GARCH model found that time-varying volatility correlations between BTC price returns and CPI was significantly weaker than that of gold return prices and CPI, suggesting more comparable properties between CPI and gold price returns than CPI and BTC price returns. In addition, Granger-causality test showed that CPI does not cause BTC or vice versa, which as mentioned, is a crucial test that was left out by Choi & Shin (2022) in their research. Despite the IRF test showing a strong response of BTC to a positive shock in CPI, the variance decomposition test showed that this change in BTC was explained by itself and not CPI shock. Therefore, given all of these points, I can state with confidence that inflation and BTC return are not positively correlated, whereas gold shows properties as an inflation-hedge.

Therefore, my results contradicts the literature of Ciaian et al (2016), Choi & Shin (2022), Blau et al (2021), as I do not find any evidence that BTC is an inflation-hedge as it fails the test when applying Bodie (1976) definition of an inflation-hedge and also performs poorly in comparison to gold in terms of inflation-hedging properties. My findings partly corroborate with Conlon et al (2021) in as much that I also do not find any inflation-hedging properties prior to the onset on COVID-19 in 2020. I believe another factor that has made my research successful and offers extra weight when comparing to the research of Ciaian et al (2016), Choi & Shin (2022) and Blau et al (2021) is down to the fact that I have provided a benchmark for BTC inflation-hedging properties to be compared against. I identified a clear gap in the literature that when assessing BTC as an inflation-hedge, the literature reviewed does not look at how BTC compares against other assets or methods in terms of inflation-hedging properties. By identifying traditional inflation-hedging assets, I was able to compare the effectiveness of BTC as an inflation-hedge against my benchmark assets. Without the comparison of BTC against a benchmark I could have concluded that BTC is an inflation-hedge as I would not have observed the below points from the DCC GARCH and VAR models:

- The significantly higher time varying volatility correlation between gold and CPI than between BTC and CPI.
- The difference in variance decomposition in the relationship between BTC/CPI and gold/CPI, which explained to me CPI explains more price variability in gold than it does BTC.
- The Granger-causality results showing the CPI granger-causes gold price.

The limitations of my research are that BTC is still very much in the infancy and is establishing itself as an asset class that can compete against traditional asset classes. Therefore, there is a limited amount of realised BTC data in comparison to other assets, which makes the makes the forecasting difficult as there is not much past data to look at, which is of course makes any model results less dependable than if we had vast historical data. The lack of realised data means we do not have enough evidence of how BTC reacts to economic downturns and monetary policy shocks, which are usually the periods in which hedging against inflation is essential for investors.

This leads me on to future research considerations, because at the time of this research we are experiencing monetary policy shocks and an overheating economy as a result of the COVID-19 pandemic, and looking at how BTC performed as an inflation-hedge throughout the turbulent economy when the Federal Reserve successfully manage to implement contractionary monetary policy.

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