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„Gold and Cryptocurrencies as inflation-hedges and safe-haven assets“

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Abstract

This study explores the inflation-hedging properties of gold and cryptocurrencies, particularly in times of high inflation. It begins by highlighting the complexity of inflation and its various interpretations, tracing the historical development of money to the digital age. The research is motivated by the frequent comparison between gold and Bitcoin, often lacking a deep understanding of their underlying structures. The central question addressed is whether gold and Bitcoin are comparable in terms of being inflation-hedging and safe-haven assets, thus justifying the notion of "digital gold", hence protection against inflation and during economic turmoil, respectively.

The study employs an OLS-model in a time-series framework, spanning from mid-2012 to mid-2023, utilizing daily price data for gold, Bitcoin, Cardano, Ethereum, Solana, XRP, and break-even inflation rates as proxies for expected inflation. Break-even inflation is defined as the difference between nominal and inflation-linked bonds that would make an investor indifferent. The objective is to assess whether these assets protect against purchasing power losses in the European context. The results reveal three key findings. In the whole period from 2012 to 2023, the relationship between these assets and inflation is inconclusive and negligible. However, a more meaningful distinction arises when the entire period is divided into pre- and post-inflation-shock periods. Gold emerges as a partial inflation hedge across the entire period, albeit in an inverse relationship during the first period; however, due to negative inflation-expectations, gold partially realizes its inflation-hedging potential. In contrast, cryptocurrencies initially play a minor role but become more significant as inflation hedges in the second period. Interestingly, variables on economic uncertainty, as instrumented by newspaper indexes, are overwhelmingly inconclusive. While gold fulfils its role as a safe-haven asset, cryptocurrencies, notably Bitcoin, do not, as they exhibit strong correlations with financial markets. In conclusion, this study rejects the notion of Bitcoin as digital gold, both in terms of inflation-hedging and safe-haven properties. It opens the door to further research as the current era of above-average inflation rates continues to evolve; thus, a final conclusion has yet to be made.

Kurzfassung

Diese Studie untersucht die Eigenschaften von Gold und Kryptowährungen als Inflationsschutz, insbesondere in Zeiten hoher Inflation. Sie beginnt mit einer theoretischen Einbettung von Inflation und gibt einen Überblick über die historische Entwicklung des Geldes bis zum digitalen Zeitalter. Das Interesse für diese Forschung ist aus dem häufigen Vergleich von Gold und Bitcoin entstanden. Die zentrale Fragestellung ist daher, ob sie in Bezug auf Inflationsschutz und als sicherer Hafen vergleichbar sind, womit die Beschreibung "digitales Gold" gerechtfertigt würde.

Die Studie basiert auf einem Zeitreihen-OLS-Modell, das den Zeitraum Mitte 2012 bis Mitte 2023 untersucht. Mit täglichen Preisdaten für Gold und Kryptowährungen sowie Break-even-Inflationsraten als Proxy für Inflationserwartungen werden diese Anlagegüter verglichen. Break-even-Inflation wird als die Differenz zwischen nominalen und inflationsgebundenen Anleihen definiert, bei der ein Investor somit indifferent wäre. Das Ziel ist es, zu bewerten, ob diese Vermögenswerte vor Kaufkraftverlusten, im europäischen Kontext, schützen.

Im Zeitraum von 2012 bis 2023 ist die Beziehung zwischen diesen Vermögenswerten und der Inflation insignifikant, was auf die deutlichen Schwankungen im gesamten Zeitraum zurückzuführen ist. Eine Unterscheidung in einen Zeitraum vor und nach dem "Inflationsschock" von 2021 ist also sinnvoll. Gold erweist sich dann über den gesamten Zeitraum als teilweiser Inflationsschutz, wenn auch in einer inversen Beziehung während der ersten Periode; aufgrund negativer Inflationserwartungen realisiert Gold jedoch teilweise sein Inflationsschutzpotenzial. Kryptowährungen werden erst in der zweiten Periode zu bedeutsamen Inflationsschutzinstrumenten. Interessanterweise sind Variablen zur wirtschaftlichen Unsicherheit, etwa durch Zeitungsindizes, überwiegend nicht signifikant.

Während Gold seine Rolle als sicherer Hafen erfüllt, ist das bei Kryptowährungen, insbesondere Bitcoin, nicht der Fall, da sie starke Korrelation mit Finanzmärkten aufweisen. Zusammenfassend lehnt diese Studie die Vorstellung von Bitcoin als digitales Gold, in Bezug auf Inflationsschutz und auf sichere Hafeneigenschaften, ab. Weitere Untersuchungen sind essentiell, da die gegenwärtige Phase überdurchschnittlicher Inflationsraten noch nicht überwunden ist, eine endgültige Schlussfolgerung steht daher noch aus.

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1. Introduction

The landscape of finance and economics is amid a profound transformation, marked by the rise of cryptocurrencies and their growing influence on global financial systems. As the pioneer and most widely adopted cryptocurrency, Bitcoin has experienced an unprecedented surge in popularity over the past few years. Cryptocurrencies, once a niche phenomenon both in academia and among the general population, have now firmly entered the mainstream consciousness. However, despite the increasing attention from scholars and policymakers, cryptocurrencies still need to be more understood, for example, in their potential role as legal tender, as exemplified by their adoption in El Salvador in 2021, which raised many regulatory questions. This seismic shift in the financial landscape raises many questions about the implications of cryptocurrencies on traditional monetary systems, the functions of central bank money, and their role as assets rather than conventional currencies. These questions extend to their potential to influence the circulation of money and even trigger shocks in the money supply if substantial amounts of cryptocurrencies were to be converted into fiat currencies simultaneously.

Meanwhile, after a protracted period of both low inflation and interest rates, the eurozone now faces levels of inflation unseen in recent decades. Simultaneously, it tries to cope with interest rates not experienced since the 2008 Financial Crisis. The European Central Bank's response, though somewhat hesitant compared to its American counterpart, FED, has involved raising interest rates. However, this reactive strategy has not yet yielded the desired outcomes in taming mounting inflationary pressures. Consequently, the combination of elevated inflation, interest rates, and uncertainties surrounding future economic developments has the potential to reshape investment behaviour.
Historically, gold has experienced long periods for which it was attributed as a financial asset with properties of a safe-haven and inflation-hedge. Recent years, particularly during the COVID-19 pandemic, have witnessed significant efforts stating Bitcoin as a novel digital manifestation of gold, as indicated by numerous newspaper articles[1]. These

[1] See, for example, (Bathija, 2021; Cuthbertson, 2023; Kuhn, 2021; Laboure, 2023; Reuters Staff, 2021; Zigah, 2020)

campaigns, often without a comprehensive understanding of the underlying structures and processes, underscore the motivation for analyzing the role of gold and cryptocurrencies in the context of inflation.
Both cryptocurrencies and gold share attributes pertinent to their roles as stores of value. While both could theoretically serve as legal tender, they now occupy a distinct space as assets rather than currencies. Therefore, this thesis embarks on an exploration of the intricate relationship between inflation and cryptocurrencies, delving into the question of whether higher inflation rates correspond to elevated returns on cryptocurrencies. The same method is applied to gold, a historical hedge against inflation, to draw comparisons between gold and cryptocurrencies. This inquiry gives rise to the following central research question:

In the context of inflation and economic uncertainty within the eurozone, do gold and cryptocurrencies exhibit properties of inflation-hedging and safe-haven assets?

Structure

The remainder of the thesis is structured as follows: Chapter 2 provides an extensive overview of inflation and its alleged causes, according to different schools of thought, and explains why inflation concerns policymakers and scholars. Further, strategies to mitigate its consequences are discussed. Finally, this chapter provides a historical overview of the development of gold and currencies, culminating in the digital era of cryptocurrencies.

Chapter 3 then presents the empirical analysis. At first, the time-series model will be explained in detail and information on the data used will be provided. Then, the findings are presented and discussed, and finally, the thesis concludes with limitations and suggests potential future research.

In conclusion, this thesis embarks on unravelling the relationship between inflation, gold, and cryptocurrencies, offering a nuanced perspective on their roles in the ever-evolving financial landscape of the eurozone. Through this exploration, the aim is to shed light on the elusive question of whether cryptocurrencies can be considered digital gold by serving as a hedge against inflation.

2. Theory

This chapter covers the main theoretical framework for the empirical analysis. It is structured as follows: First, inflation will be explained as an economic phenomenon. This includes an overview of different schools of thought, the costs of inflation and even hyperinflation, the concept of measuring inflation and how an asset might serve as a hedge against inflation. Afterwards, an overview of gold and the historical origins of gold as currency, as well as its potential as inflation-hedge, is provided, which is followed by a section on digital money and concludes with a brief summary of cryptocurrencies. Finally, a literature review will compare different insights concerning the inflation-hedging properties of gold and cryptocurrencies before the next chapter presents the empirical part.

2.1. Inflation

2.1.1. Schools of thought on inflation

In a formal talk in 1983, the Austrian economist Fritz Machiup summed up the complex phenomenon of inflation in an accurate yet witty way. As he explained in his opening statement, he could easily imagine the following controversial discussion - regarding the political economy of inflation - taking place:

> "Well, inflation—it's a monetary problem. No, it's a fiscal problem. No, it's a monopoly problem. It's a labor-market problem. It's a sociological problem. It's a distributional problem. It's a psychological problem. It's a game-theoretic problem. It's a system-theoretic problem. It's an ideological problem. It's a moral problem. It's a political problem." (Machlup, 1983, p. 15)

He then continues to admit that all of these implications were correct - in some way or another. This amusing example illustrates the complexity of inflation and that little has changed in this field, as people are arguing on the cause and effect of inflation today as several years ago. Recent debates regarding soaring inflation rates illustrate the lack of consensus within the scholarly community regarding the intricate dynamics at play. Therefore, this chapter tries to compare different schools of thought regarding the origins of inflation.

Firstly, let us define inflation as "[...] a general upward pressure on all prices, independent of idiosyncratic supply shocks. Inflation, in this sense, is a macroeconomic, aggregate concept." (Tooze, 2021)

Hence, according to this basic definition, inflation denotes a macroeconomic phenomenon which does not consider idiosyncratic shocks, i.e. microeconomic phenomena in certain sectors. Inflation describes an increase in the overall price level, not reduced to certain goods. On the one hand, this complexity makes it worthy of closer examination. On the other hand, this complexity arises precisely from the fact that it does not merely describe various isolated microeconomic phenomena that collectively contribute to an overall increase in the price level.
Historically, there have been different attempts to shed light on this economic principle - which has led to quite contrary results. An overview of different explanation approaches is shown in Table 2.1 below. The left column depicts different schools of thought, and the first row denotes different drivers of inflation. If said school of thought views a factor relevant in driving inflation, it is denoted by x; it is empty otherwise. It is denoted by (x) if a specific driver is relevant only from the point of view of subdisciplines or if its role is controversial among advocates of a specific school, as it is not always straightforward to clearly identify the causal effects.

The following paragraphs will compare different schools of thought and elaborate on inflation's different causes and effects.
The first discussed will be the *(Neo-)Classical Theory or Monetarism.* Monetarism is one of the oldest theories and was coined particularly by proponents like Adam Smith, John Locke, David Hume and David Ricardo, to name a few. David Hume, for example, discusses the role that different quantities of gold and silver might have in an economy and comes to the following conclusion

> "All augmentation[1] has no other effect than to heighten the price of labour and commodities; and even this variation is little more than that of a name. [...] Money having chiefly a fictitious value, the greater or less plenty of it is

[1]of gold and silver

School of thought	Money supply	Capacity utilisation /slack	Expec -tations	Cost push (wages)	Demand pull	Conflicting claims	Markup policies
(Neo-)Classicism /Monetarism	x						
New Keynesian theory	x	x	(x)	(x)	(x)		
Post-Keynesian theory			x	x	x	x	x
Modern Monetary Theory				x	(x)	x	
Political economy	x					x	(x)
Sociological theory			(x)	x		x	

Table 2.1.: Economic schools of thought on inflation
(Barta et al., 2021)

> of no consequence, if we consider a nation within itself [...]." (Hume, 1752, p. 269f.)

Hence, a higher quantity of money increases the nominal value of goods but has no real effect in a closed economy. Hume considers the influx of money rather as an exogenous phenomenon, e.g. through a current account surplus. Contrary to this view, Adam Smith argues in favour of the "real bill"-doctrine, which states that banks create money according to the needs of the economy; hence, increased demand is the cause of the increased quantity of money, which results in an increase in prices (Anderegg, 2007, p. 155f.). In the words of another famous proponent of the monetary school of thought, Milton Friedman, who argues

> "[...] that inflation is always and everywhere a monetary phenomenon in the sense that it is and can be produced only by a more rapid increase in the quantity of money than in output. However, there are many different possible reasons for monetary growth, including gold discoveries, financing of government spending, and financing of private spending." (Friedman, 1996, p. 17f.)

His line of argument is based on the infamous quantity equation of money developed by Irving Fisher.

$$MV = PT \tag{2.1}$$

which translates into quantity of money multiplied by velocity equals prices multiplied by the volume of transactions (Friedman, 1996, p. 5). Hence, an increase in M must result in an increase in P, cet. par. Alternatively, to put it in words, if the amount of goods in the real economy and the velocity of money remain stable, then an increase in money supply (e.g., caused by central banks) inevitably drives the price level. In this school of thought, money plays a clearly "neutral" role, hence not being associated with the real economy in the following sense: If the set of relative real prices determines an economy, it remains unaffected when the money supply changes. An increase in the money supply would only lead to a rise in nominal demand, resulting in increased prices, while the relative real prices — expressed as one good in terms of another— remain unchanged. The Neoclassical school of thought is also closely related to assumptions like Say's Law[2], the Phillips Curve[3] and that the major role of money is easing transactions. In this notion, idiosyncratic shocks[4] could never lead to a general price increase, as it would just shift demand from one good to another (Barta et al., 2021). However, as critics have outlined, the quantity equation is true by definition but does not say anything about causation, as the chain of events could go either way. Increased money supply could increase prices, but the other direction could also be true, namely higher prices resulting in a higher demand for money. Hence, the equation is true by definition (Fix, 2021).

The *New Keynesian theory* combines the theory of Neoclassics above with key elements from John Maynard Keynes's work, i.e. stickiness of wages and prices. The postulation is basically the following: due to political and/or technical reasons, prices can not change arbitrarily but take time to adapt and might have lower or upper bounds (i.e. maximum or minimum prices). If additional Central Bank money is issued, it only causes inflationary tendencies if and only if it is used by private agents or the government via fiscal spending to foster goods consumption. However, if the excess money is saved in banking accounts or the state refuses to increase fiscal spending, the result is asset price inflation rather than inflation in the real economy. Price shocks may affect inflation rates in the short-term; in the long-term, prices return to the initial level. According to this school of thought, lasting inflation levels are caused only by (near) full employment, i.e., a scenario where employers are in direct competition with each other for the (remaining) labour force, which, in turn, results in a continuous wage increase. Through an increase in the factor

[2]Every supply creates its demand.

[3]Which postulates an inverse relationship between unemployment and inflation, i.e. high unemployment goes hand in hand with low inflation rates, and vice versa.

[4]E.g. oil price shocks or gas price shocks.

price of labour, which ultimately will affect the whole economy, the price levels will rise. The main difference compared to the Neoclassical school is that wages are viewed to exceed their marginal value under certain conditions. Therefore, a specific level of unemployment is necessary in order to prevent long-term upward pressure on prices. This specific level is also called the natural level of unemployment or Non-Accelerating Inflation Rate of Unemployment (NAIRU). Hence, if the inflation matches the NAIRU, price levels are thought to be stabilized at a certain level. Unemployment above NAIRU will lead to deflationary tendencies, as bargaining power for workers decreases, resulting in downward pressure on wages, and as outlined above, unemployment below NAIRU causes inflationary tendencies (Barta et al., 2021; Mankiw, 2016). For an overview and discussion of recent developments in New Keynesian economics, see, for example, Galí, 2018.

In *Post-Keynesian theory*, the very existence of long-term macroeconomic equilibria is questioned. There might be one, but it is no key assumption. Hence, no certain long-run equilibrium equates to markets that are not clearing at all times, which instantly questions Say's Law that states supply creates its own demand. Rather than claiming the neutrality of money, it is viewed as an endogenous variable (Barta et al., 2021). An important variable in explaining output gaps is effective demand, which considers individual decisions based on their socio-economic background:

> "Effective demand in post-Keynesian analysis implies that it is scarcity of demand rather than scarcity of resources that is to be confronted in modern economics, so that output is ordinarily limited by effective demand, although it is recognised that supply constraints are present in modern capitalist economies. Individual choice is heavily influenced by income, class and the technical conditions of production, as well as by relative prices, so that income, not just substitution effects, along with income distribution amongst social classes, become the main objects of analysis. It is also recognised that individual behaviour is determined by social, conventional and institutional factors." (Arestis, 1996, p. 112)

As equilibria are viewed as completely arbitrary, there might be multiple or continuous ones that are undetermined or unattainable. Hence, in Post-Keynesian theory, the concept of NAIRU becomes obsolete. Additionally, to argue that there is no compelling theoretical foundation of NAIRU, Post-Keynesians also show that empirical data delivers little evidence that keeping unemployment at a certain level helps contain inflation (Galbraith, 1997, p. 95ff.). In Post-Keynesian theory, there is no specific line of argument explaining inflation. On the one hand, the quantity theory of money (see equation 2.1) is widely accepted, though, on the other hand, different consequences are drawn: rather than Monetarists claiming higher money supply stipulates price levels, Post-Keynesians argue it is exactly the other way around, namely, the number of goods in the real economy at a certain price level result in the nominal money demand. Hence, inflation mostly results from economic agents' expectations of wages and prices and individual actions on an aggregated level (Barta et al., 2021). Another explanation is the so-called conflicting claims approach to inflation. According to this theory, workers and firms compete over aggregated national income. If the sum of workers' and firms' claims succeeds in total available national income, it manifests in inflation, i.e. an upward pressure on prices. Workers' channel is nominal wage negotiations while firms target markup prices (Isaac, 2001, p. 508). According to the so-called wage-cost markup approach on inflation, there is one key driver of inflation, namely the growth rate of wages above the growth in labour productivity. In order to prevent wage-cost driven inflation, policymakers could either implement income policies controlling the growth rate of wages or guarantee for a reserve army of labour via aggregate demand policies, i.e. preventing full employment due to dampened demand (Atesoglu, 2001, p. 511). While the conflicting claims approach is closely related to the Political economy approaches (see below), the wage-cost approach is similar to the New Keynesian concept of NAIRU.

Modern Monetary Theory (MMT) views money as an endogenous variable, like the Post-Keynesian approach. Central Banks do not simply create money; they merely might attempt to influence private money demand by setting the nominal interest rate. A sovereign currency system, i.e. a country issuing its own currency, has the greatest possible degree of domestic policy space as it is not dependent on a foreign currency, nor is its domestic currency pegged to gold, for example. Consequently, the state has ultimate freedom concerning monetary and fiscal policies (Wray, 2015, 2f.). Within MMT, inflation can only be explained as the result of prices on the goods market or an imbalance between supply and demand. Here, expectations are not viewed to affect inflation levels. However, conflicting claims between workers and firms and price shocks, such as energy, drive inflation. Additionally, the main control tool for inflation is considered fiscal spending (ideally not limited by foreign currencies). If the issuance of legal tender creates more effective demand than there are available goods, prices must rise. If the economy suffers from inflationary pressures, e.g. due to wage growth, the state can counteract with tax increases. Accordingly, if deflationary pressure due to private defaults threatens price level stability, the government can reduce taxes to foster aggregate private consumption. However, it is important to mention these actions should be implemented ex-ante, as otherwise, business cycles might be exacerbated if the reactive measures are implemented ex-post, that is, when inflation has already taken hold (Barta et al., 2021; Freitag, 2020).

In the field of *Political economy*, various approaches are established, and some differ substantially. Broadly speaking, Political economy analyses how political forces affect the economy and, in turn, assesses how the economy affects politics (Frieden, 2020, p. 7). Politics, in this sense, covers a wide range of different concepts, institutions and the such. For a historical overview of the conceptualisation of different approaches, see the work from Marlin-Bennett and Johnson, who cover the range from ancient philosophers (who laid the groundwork for later economists) over classical economists to critiques from Marxian, feminist or postcolonial points of views (Marlin-Bennett & Johnson, 2021).

One view within the Political Economy School is called Modern Political Economy, with its foundations drawn from the neoclassical consensus that money is neutral, but it comes along with one central question: So if money is neutral and inflation comes with detrimental consequences, why is there inflation to be experienced? According to proponents of this approach, the explanation for the occurrence of inflation is rooted in the role of the state. The state is viewed as an autonomous political actor, namely as an egoistic rent-seeking maximizer who benefits from inflation to some degree. How might a state benefit from inflation? On the one hand, inflation might affect a state's wealth positively, namely directly through raising nominal wages within a progressive tax structure or indirectly through a quasi-tax on cash holdings, as the real value of cash holdings is decreasing and therefore forces people to spend more money in nominal terms, hence increases taxes. Additionally, the real value of government debts decreases. Consequently, fiscal spending becomes more easily affordable. On the other hand, inflation can also influence a government's political power. In a short-time scenario, like governments facing elections, exacerbated public spending might benefit the political incumbent, at the risk of increasing future inflation rates. This phenomenon is denoted as the political business cycle. In order to prevent governments from direct manipulation through monetary policies, independent institutions have been implemented, i.e. Central Banks. The crude argument is that independent central bankers are not tempted to manipulate inflation rates for short-sighted vote-seeking (Kirshner, 2001, p. 44f.). However, whether the independence of Central Banks can, in fact, be guaranteed has been questioned several times by critics. Especially since the global Financial crisis in 2008, Central Banks have become significantly more powerful. They can react to crises very quickly and with much monetary power. However, as critiques argue, their monetary policy tools are not subject to parliamentary or democratic control (Wullweber, 2021, p. 17).

Within the *Marxian Political economy*, inflation is mostly explained via conflicting claims and structural developments. Hung and Thompson, for example, argue that inflation/deflation results from distributional struggles between classes, i.e. capital and labour. They trace high inflation rates in OECD countries in the 1970s back to a strong working class and the following lower inflation rates in the 1980s on a neoliberal advance resulting in a diminished stronghold of workers paired with more international competition. Hence, a downward pressure on wages. They also argue that while the high inflation rates in the 1970s decreased inequality and hurt capital owners more, the low inflation rates until the Financial crisis increased inequality substantially and fuelled a financial boom resulting in the crisis 2008 (Hung & Thompson, 2016). In their words, inflation can be best explained by "class power perspective. According to this perspective, workers' power vis-à-vis capital is the most significant determinant of the inflation rate. The reason for this is that empowered labor forces capital to yield to demands for wage increases, bringing upward pressure on prices, while working-class disempowerment leads to wage stagnation and weaker inflation rates." (Hung & Thompson, 2016, p. 448) Another approach addresses conflicting claims of the produced value. The crude argument goes as follows: if economic agents seek to raise their wealth by increasing prices, others might imitate them. This approach depends largely on power relations, but if a substantial share of organized agents (large companies with a substantial market share) increases prices, they unfold a power struggle between capitalists, but also between capitalists and workers, each aiming for a larger part of the socially created surplus - capitalists through profits and workers through wages. The inevitable result is an upward pressure on prices[5] (Sawaya, 2013). For a more elaborated argument, see, for example, (Wright, 2000). However, recent literature supports the argument that increased profits are fuelling current inflation rates within the eurozone. See for example (Hansen et al., 2023; Tölgyes & Picek, 2023).

The perspective of *Critical Political economy* comes to the following conclusion: there exists a potential and enduring disparity between the purchasing power of consumers and the prevailing prices of goods and services within the market. This phenomenon is intricately linked to how businesses formulate pricing strategies, taking into account their costs (labour, capital, land) and market competitiveness. Production costs are, to some

[5]This view shows astonishing similarities to the conflicting claims approach within Post-Keynesian thought, see above.

extent, mitigated through the utilization of bank credit. Notably, the impact of interest is crucial in driving differential inflation, as it is transferred to consumers, thus influencing overall price levels. Additionally, the structure of debt financing has the capacity to trigger cyclic episodes of overproduction or underconsumption, ultimately resulting in Central Banks stepping into the role of lenders of last resort. This becomes necessary if the optimal maturity transformation into the future has been exhausted, i.e., a structural gap between production/consumption and the mechanisms financing this relationship, leading to market disruptions (Barta et al., 2021).

The *Sociological theory* sceptical of purely economic attempts to explain inflation. While there are obvious economic truths inherent to inflation, proponents of the Sociological school doubt that economists can fully comprehend the underlying structures and processes. The basic question that remains is a simple *"Why?"*. John Goldthorpe, for example, sums up the major explanations of inflation (monetary expansion, cost-push, wages/organized labour) but postulates that these views and chain of arguments still lack a substantial answer, namely the answer to the question of why. Why would governments (which are in basic monetarist view responsible for monetary expansion) or central banks behave this way if the consequences are detrimental? Goldthorpe argues in the same way regarding cost-push inflation due to organized labour; why would labour unions, for example, push wages to a level detrimental to its members? The obvious answer would be irrational behaviour. (Goldthorpe, 1978, p. 187ff.) Goldthorpe does not accept this simple answer and claims that the decisive element cannot simply be accepted as an exogenous variable in explaining inflation; he rather emphasizes that within the perspective of Sociological theory, underlying structures and phenomena must be specified:

> "It must be to investigate how inflation, understood as the monetary expression of distributional conflict, is ultimately grounded not in error, ignorance or unreason on the part of the actors involved, in the way that economic analyses are constrained to suggest, but rather in on-going changes in social structures and processes. And moreover, once such changes are established as analytically basic, the goal and potential of sociological analysis should then be to show how the actions of rank-and-file employees, union leaders, governments etc. are, if not rational in the economist's sense, still intelligible." (Goldthorpe, 1978, p. 195)

There are, of course, other perspectives that differ in their arguments. However, the ones mentioned are sufficient for a rough overview of various approaches and for illustrating that inflation is by no means a consensual phenomenon.

2.1.2. Costs of inflation

> "Rephrasing Milton Friedman's famous dictum, we claim that *inflation is always and everywhere a phenomenon of structural change.*" (Nitzan, 1992, p. 1, emphasis in original)

Economists are equally divided regarding the costs caused by high inflation as they are regarding its root cause. However, there is broad consensus on two things regarding the real costs evoked by inflation rates: 1) The costs depend on various external circumstances, particularly how policymakers respond to them. Proper policy reaction might smooth out the consequences. 2) The costs depend substantially on the actual level of inflation and its volatility. However, higher levels of inflation tend to correlate with higher volatility. The classical costs that are relatively consensual among scholars can be summarized as follows:

1. Distortions in Taxation: Inflation distorts taxation by causing people's nominal wages and income to increase, which can push them into higher tax brackets without a corresponding increase in their real purchasing power. This results in higher tax burdens for individuals, potentially creating an unfair and inefficient tax system. Similarly, fixed deductions, exemptions, and tax brackets in personal income taxes can unintentionally lead to higher real rates of taxation on individuals. This situation reduces real incomes and aggregate demand, and inadequate adjustments for inflation in government budgets worsen these effects.

2. Distortion of Interest Rate Taxation: Taxing nominal interest rates without factoring in inflation can inadvertently lower the actual return on savings by eroding the inflation compensation within the interest rate. This diminishes incentives for saving and investing, potentially distorting saving rates and economic growth models. Such taxation, rooted in traditional accounting approaches, may unintentionally hinder saving and investment, negatively impacting overall economic efficiency and growth.

3. Loss of Value of Cash ("Shoe Leather Costs"): Inflation erodes the value of cash over time since cash does not earn interest. The term refers historically to the wear and tear on individuals' shoes due to more frequent trips to the bank. However, it simply denotes incurring additional transaction costs.

4. Menu Costs: Businesses must change and adjust prices frequently due to inflation, incurring costs associated with updating menus, price tags, and other marketing materials, which can lead to inefficiencies and additional expenses for firms.

5. Distortions in Relative Price Levels: High inflation can disrupt the signalling function of prices. Consumers and producers may struggle to distinguish between relative price changes driven by market dynamics and those caused by general inflation. This can lead to misallocations of resources and distortions in production and consumption patterns.

6. Uncertainty and Contract Uncertainty: Volatile inflation creates uncertainty about future price levels, making it harder for businesses and individuals to make long-term contracts and financial plans. This uncertainty can lead to inefficiencies, reduced investment, and increased risk.

7. Impact on Economic Growth: High inflation can negatively impact economic growth. It reduces purchasing power and erodes savings, decreasing consumer spending and potentially lowering investment. The uncertainty and instability caused by inflation can discourage economic activity and hinder long-term growth.

8. Complication of Economic Life: Inflation introduces complexities into everyday economic activities. People need to constantly adjust their expectations and calculations due to changing prices, which can complicate financial planning, decision-making, and resource allocation (Miles et al., 2005, p. 265ff. ; Horwitz, 2003, p. 78ff.).

There are, of course, further costs that stem from inflation; however, they are less consensual. There is broad consensus among scholars that a significant distinction exists between expected (or anticipated) and unexpected inflation. Ackley, for example, argues that unanticipated inflation leads to changes in relative prices, resulting in unjustified redistributions of income and wealth. Unjustified in the following sense: these redistributions occur without any economic benefit, affect both economic classes and individuals, and are not subject to political consensus. Inequalities are exacerbated when the general price level changes. The fact that prices and wages do not respond to inflationary forces at the same speed further amplifies these redistributions. He further describes the impact on economic decisions over time. Economic arrangements that span over a longer period are inevitable. People make decisions based on price level expectations, whether in contracts for future payments or earnings. When these expectations are unmet, unexpected income and wealth distribution changes occur, particularly affecting agreements over extended periods, such as long-term debts and contracts. Also, in most states, there is a delay in price and wage adjustments. Due to market imperfections and the behaviour of market participants, prices and wages do not adjust immediately but with a delay, leading to inconsistent adjustments and exacerbating the redistributive effects of inflation. The effect on the social structure of a society is also noteworthy. The redistributions caused by inflation affect various economic classes and groups, such as retirees dependent on fixed-income securities, which can lead to social tensions and uncertainties. In addition, the social impact should be considered. Inflation influences social cooperation and people's attitudes towards each other. Unjustified redistribution leads to dissatisfaction and insecurity, ultimately affecting social and political stability as well as economic efficiency. Overall, Ackley argues, the costs of inflation go beyond mere financial losses and have significant implications for social and economic dynamics (Ackley, 1978, p. 149ff.). Even though this article seems somewhat outdated, its messages are relevant to this day, as it argues that inflationary costs might not be very well measurable and predictable in simple economic terms. Especially with regard to macroeconomics, economists struggle to measure and understand these effects on distribution and production fully. While some countries have managed to cope with high inflation rates without complete breakdown, complex market-oriented economies may face greater challenges. Inflation complicates government fiscal and monetary policy-making as public perception diverges from policy realities. Policymakers may make contradictory statements, expressing intolerance for inflation while avoiding solutions with associated costs, leading to a decline in public discourse quality (Ackley, 1978, p. 152f.). To sum it up, inflation has significant effects that can be categorized into three main areas: microeconomic impacts on businesses and individuals, macroeconomic consequences, and non-economic or social repercussions. Microeconomic effects include income distribution disparities, hindered business planning and investment, additional operational costs, and tax distortion. Macroeconomic effects encompass negative impacts on saving, financial markets, competitiveness, currency value, unemployment, and growth. Non-economic effects, such as social unrest and moral implications, also play a role. While some argue for inflation's positive aspects compared to deflation or concerning debt reduction – a reminder that one should be cautious about what they wish for because it might become unmanageable (Moosa, 2014, p. 119f.). Horwitz proposes another cost with regard to inflation that is not considered in standard models and is, however, also hard to quantify in economic terms. He suggests considering coping costs. The sheer existence of inflation distorts societal resources away from productive activities as a substantial share of an individual's time and resources might go into inflation-hedging efforts. These efforts can take various forms, e.g. more attention than usual to fiscal

and monetary policies by governments and central banks, comparing prices more than usual to find the best deals and then hoarding, but also shifting assets from one form to another or hiring financial consultants and the such. On a micro level, this depends substantially on the personal financial and socio-economic situation. In an aggregated macro perspective, this might influence expectations on future economic development (Horwitz, 2003, p. 86f.).
Noteworthy, however, are the relatively uneven consequences of inflation. Poorer households tend to be affected more drastically by rising prices than more affluent households: poorer individuals tend to spend a higher share of their dispensable income on essential goods than others and usually have fewer savings or assets that might generate revenues. Furthermore, the impact of economic uncertainty on personal mood, psychologically speaking, is more pronounced among poorer segments of the population (Barta et al., 2021).

2.1.3. Hyperinflation

When addressing the question of why very high inflation rates (hyperinflation) should be prevented, Keynes summarizes his response in the following manner:

> "Lenin is said to have declared that the best way to destroy the Capitalist System was to debauch the currency. By a continuing process of inflation, governments can confiscate, secretly and unobserved, an important part of the wealth of their citizens. By this method they not only confiscate, but they confiscate *arbitrarily*; and, while the process impoverishes many, it actually enriches some. The sight of this arbitrary rearrangement of riches strikes not only at security, but at confidence in the equity of the existing distribution of wealth. [. . .] As the inflation proceeds and the real value of the currency fluctuates wildly from month to month, all permanent relations between debtors and creditors, which form the ultimate foundation of capitalism, become so utterly disordered as to be almost meaningless; and the process of wealth-getting degenerates into a gamble and a lottery. Lenin was certainly right. There is no subtler, no surer means of overturning the existing basis of society that to debauch the currency. The process engages all the hidden forces of economic law on the side of destruction, and does it in a manner which not one man in a million is able to diagnose." (Keynes, 1920, p. 220f., emphasis in original)

There is broad consensus about the catastrophic economic (and social) consequences

of hyperinflation, but less consensus exists regarding the origins of hyperinflation. Furthermore, the threshold for inflation becoming hyperinflation is completely arbitrary. However, it often is characterized by exceeding 50% per month. To illustrate such rates: If the inflation rate reaches 50% per month, it signifies that prices will surge by over 100 times in a year and by more than 2 million times in three years. Note, however, that 50% is by no means an upper bound on inflation rates (Mankiw, 2016, p. 126).
The debate over hyperinflation revolves around whether it is simply an intensified form of moderate inflation or whether it has completely distinct root causes. Some economists emphasize that hyperinflation differs fundamentally from regular inflation due to its collapse of confidence in money, triggering a rapid flight into real assets and goods. On the contrary, others argue that hyperinflation can be seen as extremely high-level inflation and essentially an extension of the same determinants, but in concentrated form, so to speak (Moosa, 2014, p. 123f.). Bernholz, for example, is a proponent of the former view, i.e. hyperinflation, not simply being an intensified form of inflation. In his words, the "[...] economic situation during high inflations is quite different from that during moderate inflations. The public no longer has any illusions about the further development of the price level." (Bernholz, 2003, p. 162) As a consequence, the real stock of national money usually decreases substantially. According to Bernholz, the reasons are threefold: 1) Initially, domestic money ceases to be used as a unit of account for major transactions, particularly for postponed payments; 2) then, its role as a reliable means as a store of value diminishes, and 3) eventually, it becomes replaced with stable forms of money, such as metal-based or foreign currencies (Bernholz, 2003, p. 162). Another crucial distinction is that moderate inflation usually emerges in rising economies and is often described as some form of "overheating", while hyperinflation is usually the result of economic depression. Regarding economic growth, the evidence regarding moderate inflation is somewhat ambivalent. However, during periods of hyperinflation, most countries tend to experience a significant decline in economic performance (Moosa, 2014, p. 125f.).
However, each case is distinct and, therefore, warrants a closer examination. One of the most well-known (and best-examined) cases of hyperinflation is probably Germany during the interwar period. According to Eichengreen, German hyperinflation can be ascribed to two major factors: the balance of payments and fiscal policies. However, the complex interplay of factors becomes evident by taking a closer look. The loss of confidence in the German mark and subsequent currency depreciation set off a destructive inflation cycle, exacerbating the budgetary deficit as the public sector's expenses outbalanced its revenues due to rising costs of goods and services. Even without currency depreciation or inflation, Germany's budget would still have faced a significant deficit eventually,

making financial measures inevitable, e.g. issuing bonds and creating money. While the fiscal view acknowledges an eventual deficit and money creation independent of inflation and currency depreciation, the balance-of-payments view recognizes that these factors worsened the fiscal crisis. Nonetheless, both currency depreciation and budget shortfalls were rooted in underlying political, social, and economic tensions. The fundamental cause of the inflation lay in the lack of consensus on tax distribution and income sharing, i.e. preventing currency stabilization efforts. This internal conflict was aggravated by international reparations disputes, resulting in severe inflation. This hyperinflation event revealed Germany's struggles and similar challenges in neighbouring countries like France, Belgium, and Italy, highlighting the widespread difficulties in achieving currency stability following the war (B. Eichengreen, 1996, p. 126f.). Extensive research has delved into the connection between hyperinflation and voting patterns/political power, particularly in Germany. The German case, in particular, has received significant attention due to the assertion that hyperinflation played a pivotal role in the emergence of Hitler and Nazi fascism. For a recent study on this topic, see, for example, Galofré-Vilà, 2023.

2.1.4. Inflation measurement

The measurement of inflation plays a significant role in economic analysis and policy-making and in shaping consumer behaviour and investment strategies. In essence, inflation refers to the change in price levels between two points, often comparing a month to the same month in the previous year. However, it becomes evident that such analyses encounter substantial challenges, such as dynamic price-setting behaviour of companies, technical progress in the examined period or simply seasonal adjustments, which means that there might be differences between measuring inflation in summer and winter due to several influential factors, e.g. holiday shopping, seasonal tourism, etc.(Ejsing et al., 2007).

Inflation indicators, such as the Consumer Price Index (CPI) and Producer Price Index (PPI), provide insights into price dynamics and consumer behaviour. Inflation measurement relies on indicators that capture price movements across various sectors. The Consumer Price Index (CPI) is a widely adopted measure that tracks changes in the costs of a basket composed of goods and services that are typically consumed by households, i.e. a representative basket of goods and services and the price change from one period to another is measured. Conversely, the Producer Price Index (PPI) focuses on ex-factory selling prices and might offer insights into inflationary pressures earlier in the supply chain.

A distinction between domestic sales and exports becomes necessary to analyse the inflationary pressures due to the PPI. The Gross Domestic Product Deflator (GDP Deflator) also reflects changes in the overall price level of goods and services produced within an economy. These indicators are crucial tools for assessing inflation's impact on consumers and producers. Despite their essential contribution to visualising inflation, these indicators encounter challenges that can affect measurement accuracy. One notable challenge pertains to the diverse composition of consumer baskets across different demographic groups, which may only equally reflect the experiences of some individuals. For instance, relatively poorer households are often more affected by inflation rates on basic goods than wealthier households. The term *core inflation* often refers to a basket that excludes volatile goods like food and energy. Moreover, considering qualitative changes in goods and services, such as technological advancements, can complicate comparisons over extended periods. Such changes distort to a lesser extent on a year-on-year analysis (Mankiw, 2016). Within the eurozone, another indicator has been established, namely the Harmonised Indices of Consumer Prices (HICP), which are defined as follows: "the comparable index of consumer prices produced by each Member State" (European Commission. Eurostat., 2013, p. 7). The HICP was developed to facilitate comparable measurements and convergence. It has been a crucial indicator for the monetary policy strategy since the introduction of the Euro. While the HICPs share a common product coverage, the index baskets and weights reflect national consumption patterns. These HICPs are available only from 1995, with pre-1995 data derived from national CPIs adjusted to HICP coverage. From end-1999 on, the HICP coverage expanded to include social services (health and education) and other areas (insurance and geographic coverage). Seasonal adjustments are made to account for price movements due to factors like varying food prices, sales prices, tax changes, and fixed-interval price increases that often occur at the same point every year (European Central Bank, 2000, p. 33). However, although implementing a eurozone-wide harmonised measurement of inflation has contributed significantly in enabling comparison across regions and economic sectors, there are still substantial variances. Especially concerning different economic sectors, significant differences remain evident in terms of changes in prices. To provide a concise overview of the diverse measurements that are used by the European Central Bank (ECB) to address underlying inflation, see Table 2.2 below. In the context of monetary policy (and, to some degree, also fiscal policy), it is crucial to comprehend the nuances in fluctuations of inflation rates on the one hand and to gain an in-depth understanding of the reasons for these fluctuations on the other hand. Therefore, the ECB has developed distinct categories for identifying underlying inflation. These measures are designed to be theoretically grounded, easy to interpret (especially about their differences), and efficient in communicating inflation trends to the general public. The primary objective is to smooth out short-term noise to reach more stable long-term conclusions that do not foster ad-hoc economic uncertainty because of short-term distortions (Bańbura et al., 2023; Ehrmann et al., 2018). There are three broad approaches to estimating underlying inflation, which are outlined below and in Table 2.2

Broad Estimation Method	Measure	Definition
Permanent Exclusion-based Measures	HICP excluding energy	All HICP items except energy
	HICP excluding unprocessed food and energy	All HICP items except unprocessed food and energy (processed food is included)
	HICPX (core)	HICP excluding energy and food
	HICPXX	HICP excluding energy, food, air travel-related items, clothing and footwear
Temporary Exclusion-based Measures	Domestic inflation	HICPX items with limited import intensity
	Trimmed means	HICP excluding items with the highest and lowest year-on-year change in each month
	Weighted median	Keeps the item located at the mid-point of the weighted distribution each month
Model-based Measures	PCCI*	The common and persistent component across HICP items from 12 euro area countries.
	Supercore	Aggregates HICPX items sensitive to slack.

Table 2.2.: Different ECB inflation indices
(Bańbura et al., 2023, p. 57)
*PCCI: Persistent and Common Component of Inflation , PCCI excluding energy.

1. Permanent Exclusion-Based Measures: Certain components are excluded permanently. For example, energy or food tends to be more volatile than other goods. Hence, the more stable and general price trends should be made visible by excluding short-term noise.

2. Temporary Exclusion-Based Measures: Certain components are excluded temporarily. For example, specific items that are highly volatile due to short-term shocks.

3. Model-Based Measures: Based on economic relationships and statistical methods, influential factors that drive inflation are identified and separated (Bańbura et al., 2023, p. 56ff.).

2.1.5. Inflation hedging properties

Considering the adverse effects of inflation as outlined above, individuals with a utility-maximizing behaviour would adopt strategies to level out the erosion of real money value. Ideally, individuals in the labour force (with income not automatically inflation-linked) negotiate income adjustments regularly, e.g., annually, considering the effects of inflation. While this would already contribute to mitigating the adverse inflation effects, it is essential to note that the consequences would then still usually only partially be offset as wage negotiations often occur ex-post in order not to fuel inflationary pressures. An additional approach could be investing disposable income, as cash[6] or even money in saving accounts[7] usually results in a loss of purchasing power. While a utility-maximizing approach might suggest spending all disposable income to avoid any depreciation, this is usually not feasible for most households as it does not consider personal preferences on consumption nor economic uncertainties regarding the future. Consequently, individuals could be involved in making financial decisions that minimize the impact of inflation on their purchasing power over time. Such actions might encompass investing in assets with inflation-hedging properties, reallocating their portfolio to include assets that tend to perform well during inflationary periods, and adjusting their consumption and saving patterns to account for the diminishing value of money.
For individuals, the question then arises of what to invest in and how to split their portfolios in order to minimize risk or to maximize rent. In order to minimize depreciation with regard to inflation, so-called inflation-hedging assets might be interesting for investors. Simply speaking, inflation hedging involves assets that tend to retain their value or even appreciate in value during periods of inflation. It is not just about assets not depreciating more than inflation, but about their ability to maintain purchasing power or provide a positive real return in the face of rising prices (Rubens et al., 1989, p. 45f.). In the context of inflation hedging, various investment forms have been examined regarding

[6]i.e. a form of money that yields no rent

[7]It depends on the nominal interest rate and the actual inflation rate. In Austria (and likely throughout the entire eurozone, given its connection to the ECB), for instance, nominal interest rates have been significantly lower than inflation rates in recent years, leading to real money losses.

their inflation-hedging properties, with ambiguous results. Nevertheless, it is crucial to note that individual circumstances play a crucial role in the context of inflation-hedging investment decisions in assets. In this regard, it is important to consider classic business fundamentals, best described by the so-called *Magic Triangle of Asset Management*. Portfolio theory distinguishes between tangible, intangible and financial assets. Based on individual needs and financial capabilities, investors have to consider the trade-offs between risk, liquidity and returns (Chvatalova & Hřebíček, 2013, p. 542).

Robert Greer distinguishes three different asset classes, so-called superclasses, each containing further subclasses. The lines between them are sometimes somewhat vaguely defined, and hybrid classes exist. However, the following three classes cover the spectrum of asset classes, namely 1) capital assets, 2) consumable/transformable (C/T) assets and 3) store of value (SOV) assets. A capital asset is described as a form that continuously creates revenues, like equities and bonds, but also income-producing real estate. In order to quantify expected revenues, the net present value is a legitimate method. C/T assets can be consumed, transformed, and have economic value, yet do not provide a permanent stream of revenues. Many C/Ts are classified under physical commodities like grain or rare metals. An important distinction is that net present value analysis does not qualify for C/Ts. SOVs cannot be consumed, nor do they generate income, but they are a sufficient store of value in regular times. Classic examples are real estate, art and rare metals. However, these distinctions are a bit blurry as they do not completely distinctly separate asset classes from each other. They give a broad overview of what basis asset classes can be distinguished. However, for example, real estate counts as a capital asset and SOV. Rare metals are classified into more than one category as well, as both C/T and SOV. Therefore, it is necessary to carefully examine an asset option to determine the benefits it should fulfil in a specific case (Greer, 1997, p. 87f.).

For individuals, the question then arises what to invest in and how to split their portfolios in order to minimize risk or to maximize rent. In order to minimize depreciation with regard to inflation, so-called inflation-hedging assets might be interesting for investors. Simply speaking, inflation hedging involves assets that tend to retain their value or even appreciate in value during periods of inflation. It is not just about assets not depreciating more than inflation, but about their ability to maintain purchasing power or provide a positive real return in the face of rising prices (Rubens et al., 1989, p. 45f.). In the context of inflation hedging, various investment forms have been examined in regard to their inflation-hedging properties, with ambiguous results. Nevertheless, it is crucial to note that individual circumstances play a crucial role in the context of inflation-hedging investment decisions in assets. In this regard, it is important to consider classic business

fundamentals, best described by the so-called *Magic Triangle of Asset Management*. Portfolio theory distinguishes between tangible, intangible and financial assets. Based on individual needs and financial capabilities investors have to consider the trade-offs between risk, liquidity and returns (Chvatalova & Hřebíček, 2013, p. 542).
Robert Greer distinguishes basically three different asset classes, so-called superclasses that each contain further subclasses. The lines between them are sometimes somewhat vaguely defined and there are hybrid classes. However, the following three classes cover the spectrum of asset classes, namely 1) capital assets, 2) consumable/transformable (C/T) assets and 3) store of value (SOV) assets. A capital asset is described as a form that continuously creates revenues, like equities, bonds but also income-producing real estate. In order to quantify expected revenues, the net present value is a legitimate method. C/T assets can be consumed, can be transformed, have economic value yet do not provide a permanent stream of revenues. Many C/Ts are classified under physical commodities, such as grain or rare metals. An important distinction is that net present value analysis does not qualify for C/Ts. SOVs cannot be consumed nor do they generate income, but they are a sufficient store of value, in regular times. Classic examples are real estate, art and rare metals. It is important to note, however, these distinctions are a bit blurry as they do not completely distinctly separate asset classes from each other. They give a broad overview on what basis asset classes can be distinguished. However, real estate counts as both capital asset and SOV, for example. Rare metals classify for more than one category as well, as both C/T and SOV. Therefore, it is necessary to carefully examine an asset option to determine the benefits it should fulfill in a specific case (Greer, 1997, p. 87f.).

Inflation hedging refers to the capacity of an asset to mitigate the adverse effects of inflation on investment returns. It involves analyzing the relationship between the returns of a particular asset and inflation rates to determine whether the asset's value can be preserved or even enhanced during periods of inflation. An asset is considered to possess inflation-hedging properties when its returns positively correlate with inflation, indicating that it can maintain its value or provide superior performance as inflation rises. The concept is rooted in the Fisher hypothesis, which suggests that nominal asset returns should reflect market inflation rate expectations. In essence, inflation hedging seeks to identify assets that can serve as a buffer against the eroding impact of inflation on investment values (Salisu et al., 2020, p. 1f.). Bodie proposes three different definitions of inflation-hedging. The first could be described as risk diversification, as it is essentially the following: investing in a risk-free nominal bond that is secure in terms of default and then investing in other securities to minimize the variance in its real return. According to the second definition, a security can be considered an inflation hedge if it provides a form of "protection" against inflation. This involves preventing or reducing the likelihood that the real rate of return on the security will drop below a specified threshold, such as zero. The third concept describes an asset as an inflation hedge if and only if its real return is independent of the inflation rate. This suggests that a change in the rate of inflation, all other factors held constant, should result in a proportional change in the nominal rate of return on equity. This relationship is often described more broadly, namely by a positive correlation between the nominal rate of return and the rate of inflation (Bodie, 1976, p. 459f.). The latter definition was first proposed by Fisher, 1930, namely in formally describing the theoretical inflation-hedging relationship through the connection between asset returns and inflation. He observed that the nominal interest rate could be represented as the sum of an anticipated real return and the expected inflation rate. Fama and Schwert elaborated on the relationship and proposed the idea that the Fisher hypothesis can be applied to basically all forms of assets because expected nominal returns contain market assessments of expected inflation rates (Fama & Schwert, 1977, p. 115). Hence, in an market that processes information efficiently in $t-1$, any asset j will be priced accordingly:

$$E_{t-1}(r_{jt}^n) = E_{t-1}(r_{jt}^r) + E_{t-1}(\pi_t) \tag{2.2}$$

With $E_{t-1}(r_{jt}^n)$ denoting the expected nominal return of an asset j in $t-1$, $E_{t-1}(r_{jt}^r)$ denoting the expected real return of said asset j, and $E_{t-1}(\pi_t)$ the expected inflation rate in $t-1$. Of course, a suitable measurement of expected inflation is a prerequisite for this formula. There are different methods, and they all have different advantages and disadvantages. Expected inflation can be calculated from theoretical relations in the treasury bill market, survey measures, time-series models, information contained in marketable securities (e.g. inflation-linked bonds) or use realised past inflation as a forecast for future inflation (See chapter 2.1.6 below) (Arnold & Auer, 2015, p. 194). If the prerequisite of reliable measurement of expected inflation is met, under consideration of Equation 2.2, the following regression model can be derived:

$$r_{jt}^n = \alpha_j + \beta_j E_{t-1}(\pi_t) + \epsilon_{jt} \tag{2.3}$$

Equation 2.3 illustrates a simple linear regression model, where the nominal return of an asset j at time t is on the left-hand side, and the expected inflation at time $t-1$ is on the right-hand side. The parameter of interest is β_j. If this parameter is not statistically different from 1, it signifies that the nominal return rate varies in (perfect) accordance with the expected inflation rate, signifying a perfect hedge against inflation. This conclusion does not contradict the assumption of independence between real return and inflation rate, as depicted by Equation 2.2 (Arnold & Auer, 2015, p. 194). While Equation 2.3, as outlined originally by Fisher, considers only expected inflation, Fama and Schwert extend the model by including unexpected inflation $\Big(= \pi_t - \big(E_{t-1}(\pi_t)\big)\Big)$ as the difference between actual inflation at time t and the expected inflation rate, which results in the following model:

$$r_{jt}^n = \alpha_j + \beta_j E_{t-1}(\pi_t) + \gamma_j \Big[\pi_t - E_{t-1}(\pi_t)\Big] + \epsilon_{jt} \tag{2.4}$$

The parameters of interest, then, are β_j and γ_j, where β_j not statistically different from 1 indicates asset j being a perfect hedge against expected inflation and γ_j not statistically different from 1 indicates said asset j being a perfect hedge against unexpected inflation. Significant values for β_j and γ_j between 0 and 1 correlate to a partial hedge against inflation. Negative values can be described as a "perverse hedge", meaning inflation-hedge can only be obtained by short-selling the asset. Short selling involves selling an asset with the anticipation of repurchasing it later when its price is expected to decrease even more. This strategy aims to capitalize on the projected price decline, allowing the investor to repurchase the asset at a reduced cost compared to the initial selling price (Arnold & Auer, 2015, p. 194).
The effectiveness of an asset as an inflation hedge varies depending on the type of asset. Intuitively, cash has a constant nominal return of zero at all times. Hence, the nominal return will remain unchanged by inflation changes, making cash ineffective as an inflation hedge. In contrast, the nominal return on a nominal bond is determined in the previous period ($t-1$), and as a result, it cannot provide protection against unexpected inflation. However, buyers of such bonds might demand compensation for the anticipated loss in value due to inflation, making the asset an ex-ante hedge against inflation. Assets like housing and equity, on the other hand, can be described as ex-post hedges as they have the potential to hedge against unexpected inflation. This is because they are tied to real assets or to ownership claims. As a result, the nominal values of these assets and the nominal yields derived from their operations are expected to increase in line with inflation

(Fehrle, 2023).

2.1.6. Expected inflation

As outlined above in Chapter 2.1.5 Inflation hedging properties, there are several considerations regarding the inflation-hedging properties of assets. On the one hand, the measurement of actual inflation presents challenges; on the other hand, there are various ways to determine expected inflation. One important notion is that all established indices of inflation are published on a monthly basis. This is partly because it is not feasible to capture daily price changes on an aggregated level to truly speak of inflation, as opposed to merely isolated market participants adjusting their prices. For evaluating macroeconomic developments and monetary and fiscal policy measures, monthly inflation rates (provided they offer insights into their composition) are sufficient most of the time as, generally speaking, long-term trends are more relevant than day-to-day changes.

However, when examining the extent to which certain assets protect against inflation, inflation rates on a monthly basis fall short of providing comprehensive conclusions. This is particularly true for swiftly price-changing or volatile assets. Especially for assets that can be traded online daily and where prices can vary even hourly, a monthly inflation rate adjustment is not satisfactory. For example, this aspect differs for real estate assets, as no permanent price adjustments exist. In the case of real estate, monthly inflation rates could be sufficient to analyse the effects on the real estate market. This is because real estate prices tend to be less volatile and evolve over extended periods. Therefore, in this context, monthly inflation rates could be more relevant to understanding long-term trends and assessing potential inflation-hedging properties of real estate. Note, however, that for analysing inflation-hedging properties of real estate, a vital variable of interest is interest rates, as especially for relatively costly assets, debt-backed financing is essential. Another issue to consider is that rent might be inflation-linked[8] (Arnold & Auer, 2015, p. 205f.).

Inflation expectations are crucial for understanding and predicting actual inflation rates. Economic theories like the expectations-augmented Phillips and New Keynesian Phillips curves illustrate how expectations influence pricing and inflation decisions. Empirical evidence supports this link, emphasizing the impact of higher expected inflation on actual inflation (Schafer, 2022). It is intuitively not surprising that the expectations of rising prices ex-ante result in an implemented higher price level ex-post. It is crucial to note that expected inflation is unobservable. Therefore, the challenge lies in measuring these

[8] See, for example, Austria.

expectations indirectly. Generally speaking, there are three common types of measuring inflation expectations: surveys of professional forecasters, consumer and business surveys, and market-based measurements.
Surveys of professional forecasters capture the expectations of economic experts. They provide long and consistent time-series data and offer short- and medium-term inflation forecasts.
As the name indicates, consumer and business surveys target consumers and businesses, respectively and poll the perception of inflation trends. Consumer expectations often cluster around round numbers and are sensitive to specific prices, making interpretation challenging as they are susceptible to bias. Both professional forecasts and consumer and business surveys come with scarce availability.
Market-based measures use asset prices, such as the break-even inflation rate derived from nominal and inflation-protected Treasury securities. However, these measures have limitations due to liquidity premiums and other factors affecting yields (Adeney et al., 2017; Moore, 2016).
The years pre-COVID show that inflation in advanced economies has been low and below central banks' targets, affecting various measures of inflation expectations. Market-implied expectations have been volatile, closely tracking headline inflation. Long-term expectations are usually more stable, reflecting central banks' credibility once short-term shocks dissipate. In conclusion, understanding and measuring inflation expectations are vital for monetary policy decisions, with market-based measures, consumer surveys, and professional forecasts providing valuable insights into future inflation trends (Adeney et al., 2017; Moore, 2016).

2.1.7. Risk management

In addition to inflation, investors must also address other risks, including mundane portfolio risks that naturally arise from investments across different sectors, as well as economic uncertainty and market volatility. Diversifying a portfolio across various asset classes, such as stocks, bonds, commodities, and real estate, can help mitigate the risk associated with a single asset class. This broader diversification allows fluctuations in one area to be offset by potential positive developments in another, reducing reliance on a single asset class and thus mitigating the risk of significant losses. In addition to these fundamental portfolio risks, investors face the challenge of economic uncertainty. Economic events, political decisions, or changes in international trade can have unforeseen effects on financial markets. To navigate these uncertainties, investors need to remain flexible and be able to adapt their portfolios to respond to changing market conditions. Among investors, various concepts for risk mitigation have been discussed. In line with portfolio theory, the distinction between "hedge" and "safe-haven" concepts were introduced (Robiyanto, 2018). They can be defined as follows:

> "A strong (weak) hedge is defined as an asset that is negatively correlated (uncorrelated) with another asset or portfolio on average." (Baur & McDermott, 2010, p. 1889)

> "A strong (weak) safe haven is defined as an asset that is negatively correlated (uncorrelated) with another asset or portfolio in certain periods only, e.g. in times of falling stock markets." (Baur & McDermott, 2010, p. 1889)

> "A diversifier is defined as an asset that is positively (but not perfectly correlated) with another asset or portfolio on average." (Baur & Lucey, 2010, p. 219)

The primary differentiating factor between these two asset types is the duration of their effects. A hedge is expected to maintain its properties on average, while a safe-haven is only required to exhibit its characteristics during certain events, such as financial crises. Assets that qualify as hedges against stocks might temporarily move in tandem with stocks during crisis periods, as in times of significant economic uncertainty, many different assets might be sold simultaneously. A possible explanation is herding behaviour. On the other hand, assets could be negatively correlated with another asset only during crisis periods but have average co-movement otherwise. Investors might seek these assets solely during crises, as they act as a safe-haven during turbulent times. The distinction between strong and weak hedges and safe havens is significant for investors. If assets are negatively correlated, one asset still yields returns in times of crisis while the other does not. However, the investor might not benefit from this phenomenon if they are uncorrelated. The diversifier does not qualify as a means to reduce losses in extreme turmoils, as similar to the hedge, its property has only to hold on average (Baur et al., 2018; Baur & Lucey, 2010; Baur & McDermott, 2010).

2.2. Gold

Gold is a term with a long history that has served different functions in various societies. Gold, valued for its rarity, durability, and beauty, played a significant role in ancient cultures. It played a role as a symbol of wealth and power, while its metallic properties made it ideal for intricate ornaments and jewellery. It served as both a means of exchange and a store of value, facilitating trade and accumulating wealth across civilizations. Additionally, gold held spiritual importance in some societies, used in religious rituals and artefacts due to its characteristics, like being not easily destructible and being thought of as having a divine association. It has been demonstrated multiple times that gold (and other precious metals) has always been closely intertwined with power structures and social relationships (Graeber, 2011; Graeber & Wengrow, 2021; Hurtig, 2020). The following paragraphs provide a brief overview of money as a medium of exchange, the historical evolution of means of payment, and digital currency.

2.2.1. The origins of money

> "Look at a coin from your pocket. On one side is 'heads' - the symbol of the political authority which minted the coin; on the other side is 'tails' - the precise specification of the amount the coin is worth as payment in exchange. One side reminds us that states underwrite currencies and that money is originally a relation between persons in society, a token perhaps. The other reveals the coin as a thing, capable of entering into definite relations with other things, as a quantitative ratio independent of the persons engaged in any particular transaction. In this latter respect money is like a commodity and its logic is that of anonymous markets." (Hart, 1986, p. 638)

When examining the history of gold, it is inevitable to delve deeper into the function and the origins of money. Karl Menger stated the question, why is it that certain commodities (coined pieces of gold and silver) are universally accepted as means of payment? Historically, other forms of commodities were used as means of exchange, e.g. cattle, skins, cubes of tea, slabs of salt or shells. Either way, this does not answer why traders were to accept some commodities they might but also might not have usage for, as their needs may already be fulfilled. Hence, the infamous double coincidence of wants occurs: Trader A (with good x and desire for good y) must find a trader B (with good y) willing to offer good y in return for good x. The next problem is that goods x and y might have different values, might not be divisible, or the quantities of x and y do not match the value of their vis-a-vis. Hence, to execute the trade, goods x and y must have equal values attributed to them by their owners, respectively. This dilemma could be solved by including more traders and goods. However, this would rather make the trade more complicated than easier. Also, the question of the durability of goods arises and so forth. The nearby answer is that, over time, certain goods began to be used more frequently as a medium of exchange due to their unique properties. These goods were scarce, durable, divisible, and easily recognisable. When people realise that many others accept a particular good and hold a high exchange value, they will increasingly accept and reuse it themselves. This fosters the usage of this specific good as a medium of exchange in a certain society. Over time, a consensus forms about which good is best suited as a general medium of exchange. This good eventually develops into a widely accepted form of money. Karl Menger emphasises that the emergence of money is based on individual actions and preferences and is not driven by state decree or centralised authority. This approach is often referred to as the "subjective theory of money" and forms a fundamental pillar of the Austrian School of Economics (Menger, 1892). Hence, the introduction of some agreed-upon form of money solves the double coincidence of wants. The popular story, as often outlined by economists and historians, is the following: in an evolutionary process, humans started to trade at some point. In order to simplify and enhance trades, some form of money-equivalent was introduced, which ultimately was replaced by scarce metals. These metals were coined at some point to prevent fraud, and in the end, fiat and then digital money were introduced. This narrative has been criticised repeatedly, for example, by the anthropologist David Graeber: "The story of money for economists always begins with a fantasy world of barter. The problem is where to locate this fantasy in time and space." (Graeber, 2011). In his book *Debt: The first 5000 Years*, he presents a different perspective on the origins of money compared to the traditional economic theory, as outlined above by Menger. He introduces the idea that money originates from social relationships and obligations, hence some form of virtual credit. He suggests that in early societies, people engaged in various forms of social interactions and exchanges without necessarily using a standardised medium of exchange. These exchanges were based on trust, social connections, and reciprocity. According to Graeber, debt played a crucial role in shaping early economies. People kept track of debts and obligations among themselves, creating a complex network of social relationships. Over time, these debt relationships could become quite extensive and challenging to manage. Therefore, money was introduced as a way to simplify and formalise debts. People began using objects with agreed-upon value as a way to settle debts. These objects eventually gained wider acceptance as a medium of exchange and became what is known

today as money. In Graeber's view, money is not just a tool for economic transactions but is deeply intertwined with social dynamics, power structures, and human interactions. He challenges the traditional narrative of money's origin and emphasises its social and cultural origins (Graeber, 2011; Graeber & Wengrow, 2021). Hence, Graber argues that the cause of events is exactly upside down. Instead of switching from barter to money to credit, he argues that credit was the first money unit.
Hurtig advocates a similar approach. He views money as an early form of taxation. After the process of settling down (often not a voluntary process), social power structures emerged within societies. In order to free the upper classes from fieldwork as they held military and religious authority, the remaining strata of the population had to contribute taxes in the form of grain and similar. As societies grew, the levies became less transparent, and quantification became necessary. Hence, an early form of money embedded in power structures in order to quantify grain (Hurtig, 2020).

In chapter 4 of *An Inquiry into the Nature and Causes of the Wealth of Nations*, Adam Smith states that metals eventually replaced other forms of money due to their unique properties:

> "In all countries, however, men seem eventually to have been led by irresistible reasons to prefer metals for this purpose. Metals can be kept without loss; hardly anything is less perishable than they are; and they can without loss be divided into any number of parts, which can then easily be re-united again, this being the quality that most fits them to be the instruments of commerce and circulation." (Smith, 2017, p. 10)

Throughout history, the usage of metals varied in cultures, with gold and silver remaining highly present and eventually replacing other forms of barter. Originally, these metals were used in crude form, which resulted in significant inconveniences: the trouble of weighing and testing. Metals can be precisely weighed and tested in order to prevent severe fraud, but it is time-consuming and, hence, simply impractical in everyday life. In order to prevent abuse and promote trading activities, most countries started to coin money, i.e. a public stamp to assure a certain quantity, hence value, of money. Before many others, Adam Smith stated that by exchanging goods for money, money takes the relative value of goods (Smith, 2017, p. 11f.). This means the value of a commodity only becomes visible in relational terms if it is expressed in terms of another good. This process is simplified via money. Later, Karl Marx will draw on this conception in his analysis.

Historically speaking, how money is utilized has undergone significant transformations. The conquest of South America resulted in a vast additional influx of gold and silver, first into Spain and then into the whole of Europe, which significantly enhanced economic activity. At times, the sudden increase of these metals led to inflationary tendencies, and it is also ascribed to Spain's decay as the dominant European power as it instead focused on consuming, hence spending its money, and thus fostering other European economic development than its own:

> "The Spanish empire in the Americas, long the dominant European overseas empire, was less concerned even with commerce than with amassing bullion, extracting its wealth from the gold and silver mines of South America. So dependent did the Spanish economy become on this treasure that many observers [...] have argued that this preoccupation at the expense of commerce or agricultural production obstructed Spain's economic development." (Wood, 2002, p. 150f.)

A much-debated and controversial topic at different points in time was how to stop the en masse efflux of valuable money in metal form in several, primarily European, states. This way of formulating the problem and several other economic and political tendencies at the time bore the origins of economic views like mercantilism or bullionism. They differ substantially, but both consider an active trade balance highly significant (Davies, 1994).

2.2.2. The origins of paper and modern credit money

The origin of paper money goes as far back as the twelfth century; it can be traced back to the initiation of municipal bonds. The Venetian government introduced this method in urgent need of funds for military endeavours; the government imposed a mandatory loan on its citizens who paid taxes. The government offered a five per cent annual interest rate in return for their contributions. It permitted these "bonds" or agreements to be traded, effectively establishing a market for government debt (Graeber, 2011). Between 1540 and 1640, Western Europe suffered from a severe price increase, the so-called price-revolution. As mentioned above, the severely increased influx of scarce metals from South America, of course, played a role in driving up prices. However, more than the monetary view is needed to explain the situation. This price rise - which took place during the Stuart period - was caused by various factors. The rapid population growth led to higher demand for goods and services, particularly food. However, productivity constraints in agriculture negatively impacted yields, resulting in an imbalance between supply and demand. Population growth per se would not have caused a problem. However, combined with people migrating to cities and changes in agriculture (the shift from labour-intensive agriculture to pastoral livestock farming for wool), the demand for food rose sharply while the supply did not. Another issue was the enclosure movement. Due to the appropriation of common land, people lost access to food. Instead, 'vagabonds and vagrants' were tried to force into the agricultural labour force. Wars, plagues and the closure of monasteries contributed to civil unrest in this period. Raised rents demanded by landowners further exacerbated inflationary pressures. These rent increases triggered protests repeatedly, highlighting society's response to price increases for specific goods. Overall, the price revolution was a complex development stemming from the interplay of monetary and non-monetary factors and social, economic, and political changes (Davies, 1994, p. 211ff.). The above-mentioned bonds spread through Europe at the same time. By the sixteenth century, merchants were already regularly using bills of exchange to settle debts; government debt bonds were the real credit money that emerged. While the previous reasons all contributed to the price-revolution, credit money laid the financial foundation for transforming the economy in this magnitude. Credit money shattered the so far-known ways of production as it led to a drastic distinction between people who had access to this form of money and those who did not, the latter being reduced to wage labourers (Graeber, 2011).

Genuine paper money - money not in credit form - was first established when the Bank of England came into existence in 1694. This endeavour was rooted in the crown's war debts. The creation of the Bank of England came about when a group of merchants offered King William III a £1.2 million loan to support his war against France. As part of the arrangement, they gained permission to form a corporation with a monopoly on issuing banknotes. These banknotes were essentially IOUs[9] representing a portion of the king's debt to the merchants. The merchants were allowed to lend these IOUs to anyone willing to borrow or deposit money, effectively circulating and monetizing the royal debt by charging interest in addition to the interest owed by the king. This institution became the first independent national central bank. Over time, these banknotes evolved into the first European national paper currency (Graeber, 2011). While paper and credit money gained in popularity, it was important for authorities to preserve trust in a currency; hence, currencies were often pegged in some form to a scarce metal with intrinsic value, usually gold or silver. In Britain, the gold standard had a unique history. While other countries operated on bimetallic standards (using both gold and silver as the basis for their currencies), Britain had been on a de facto gold standard since 1717[10] and a fully

[9] I owe you, certificate of debt.

[10] Due to an overvaluation of the silver price, which led to silver coins leaving circulation, see Gresham's

legal gold standard from 1821. During the Napoleonic Wars, inflation and suspension of convertibility occurred. However, in 1819, a law required the Bank of England to make its notes redeemable in gold at the market price prevailing in 1821. This marked the beginning of the gold standard in Britain. While Britain adopted the gold standard early, other countries were slower to follow due to concerns about inflation resulting from gold discoveries. Bimetallic standards were common, with countries ready to transform gold or silver into coins. The bimetallic countries operated two commodity price stabilization schemes, pegging their currencies to gold and silver standards. The United States and France, among others, operated under bimetallic standards. An international conference in 1867 failed to establish a common standard. Instead, individual governments like Germany adopted the gold standard, followed by other countries. By the early 1900s, much of the world had embraced the gold standard (B. J. Eichengreen & Flandreau, 1997a, p. 5ff.).

2.2.3. Gold standard and Bretton Woods

The gold standard emerged in the 19^{th} century as a response to the instability of paper currencies. Under this system, a currency could be exchanged for a fixed quantity of gold. Countries with an implemented gold standard minted gold coins with specified weights and a fixed ratio of gold content. Before coin minting, verifying and comparing the purity of coins was challenging, leading to instances of fraud (Graeber, 2011). Additionally, central banks maintained substantial gold reserves to ensure the convertibility of their currencies. While the gold standard provided price stability and bolstered confidence in currencies, it had limitations. It could only adapt the money supply to economic needs at some times as the availability of hard currency limited it. Therefore, at times, deflationary tendencies and economic turmoils were provoked. During both World Wars, many nations were compelled to abandon the gold standard to finance their war machinery, resulting in currency devaluation, hyperinflation and devastating social and economic consequences. Following World War II, representatives of major industrial nations assembled in a historic meeting in Bretton Woods, New Hampshire, to establish a new international monetary system. The Bretton-Woods Agreement of 1944 introduced a fixed exchange rate system, with the U.S. dollar as the key currency pegged to gold and other currencies valued in relation to the U.S. dollar but not directly pegged to gold anymore. While the European industrial nations were devastated by the wars and the economic turmoils of the inter-war period, the U.S. economy registered significant growth, therefore seeing it fit, superseding

Law.

Great Britain as the new hegemonic power. The Gold Standard era eventually ended in the 1970s when the United States abandoned the dollar's gold backing. This transition ushered in a flexible exchange rate system where market forces determined currency values (Davies, 1994; B. Eichengreen, 1996; B. J. Eichengreen & Flandreau, 1997b).
While some economists emphasize that it was only by abandoning the gold standard that modern requirements of an increasingly globalized economy, with a substantial increase in money demand, could be met, some critics claim that it was only with the decoupling of currencies from a fixed value object that speculation and money creation of the magnitude known today became possible, which they see as a significant contributor to economic crises. See for example (Kostakis & Giotitsas, 2015; Wullweber, 2021).

2.2.4. Gold and inflation

> "We show that gold may be an effective hedge if the investment horizon is measured in centuries. Over practical investment horizons, gold is an unreliable inflation hedge." (Erb & Harvey, 2013, p. 1)

In popular thought, gold is believed to serve as a somewhat reliable inflation-hedge. Even though, for regular short-term investors, this might not hold, there are several reasons for this prevailing narrative. Foremost, simply by historical significance. Gold has a long and impressive history as a store of value and protection against inflation. It has been used as currency and a medium of exchange across various cultures and eras. Gold possesses intrinsic value as a precious metal, and its supply is relatively finite. The difficulty of gold extraction and its limited availability adds to its appeal as a stable investment. Therefore, gold can preserve its purchasing power over extended periods. From the 1830s until the 1920s, it was stabilized continuously at a value of approximately $21[11] under the gold standard. For a detailed report on the long-term performance of gold prices and returns, see, for example, Harmston, 1998. Only with the abolishment of the gold standard in 1970 came a drastic surge in its value (as seen in Figure 2.1); yet, its value has not depreciated significantly since (in relation to its historical values). Only after the financial crisis in 2007-08, it experienced a drastic slump. In contrast to fiat currencies, which can be eroded by inflation, gold retains its intrinsic value; therefore, gold is often called a "safe-haven" asset. During times of economic uncertainty or financial crises, investors often turn to gold as a refuge from market volatility[12]. Therefore, gold is commonly included in investment portfolios to diversify risk. It serves as a (partial) hedge against currency

[11] See (SD Bullion, 2023).
[12] Hence, it is said to be uncorrelated with classical financial assets in terms of economic turmoil.

risks and inflation, contributing to overall risk reduction. Since gold is often priced in US dollars, it can act as a hedge against currency devaluation. When the dollar weakens, the nominal price of gold often rises, preserving its real value. In recent years, investor interest in gold, mainly through Exchange Traded Funds (ETFs), has surged while the supply remains constant. Investors increasingly view gold as a means to safeguard their wealth,

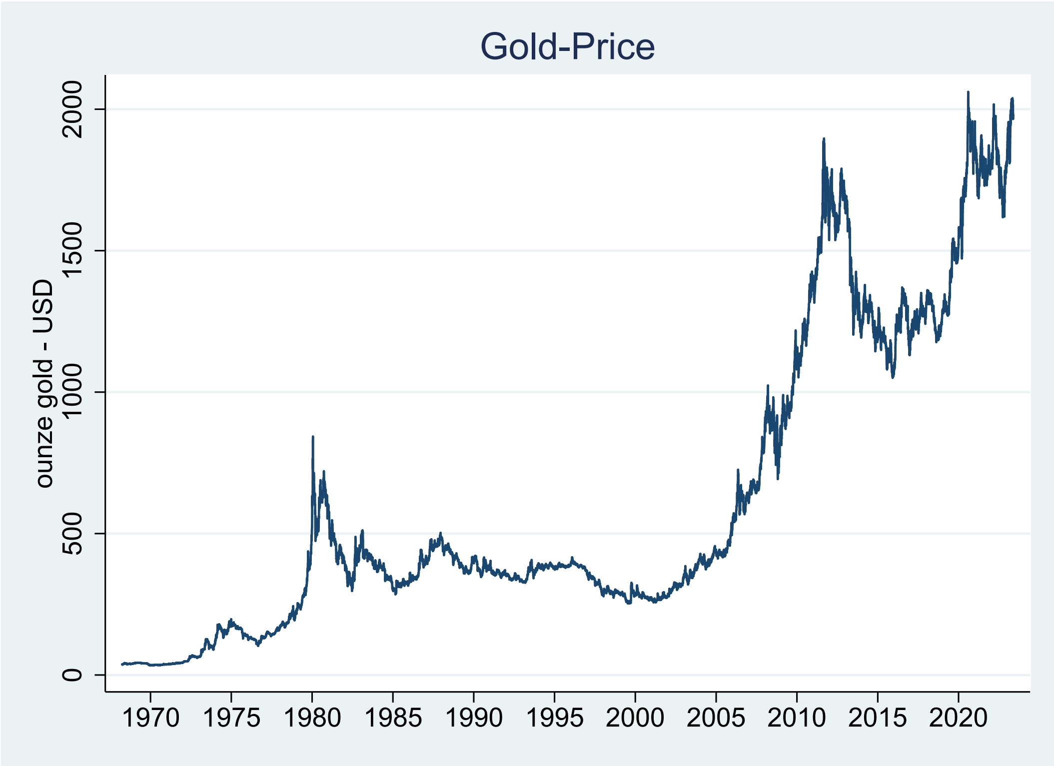

Figure 2.1.: Development of gold prices

especially in times of uncertainty. In summary, the enduring appeal of gold as an inflation hedge is based on its capacity to maintain wealth, act as a safe haven during turbulent periods, and offer diversification advantages to investment portfolios. Its intrinsic value, limited supply, and countercyclical demand reinforce its position as a reliable asset for safeguarding wealth during economic turbulence and inflationary pressures. However, it is essential to note that the effectiveness of gold as an inflation hedge can vary over time, has also been assessed differently in various studies and might also be susceptible to geographic regions (Arnold & Auer, 2015; Baur & Lucey, 2010; Baur & McDermott, 2010; Baur & McDermott, 2016; Ghazali et al., 2012). Arnold and Auer examine several studies concerning inflation-hedging properties of different assets, among them gold. They conclude the following:

> "Summarising the evidence on the empirical relationship between gold and inflation, we can say that most of the earlier studies in the field report evidence that gold prices and inflation are cointegrated while more recent work published after the financial crisis in 2008 presents a less favourable picture. The latter studies show that the link between gold and inflation is either non-existent, merely driven by outliers or strongly time-dependent. In some periods, gold has outperformed inflation, while in other periods gold has failed to match it." (Arnold & Auer, 2015, p. 202)

It is, therefore, evident that its function as an inflation-hedge is far from consensual and also varies over time. It may be the case that it is nowadays mostly a narrative that benefits from its past success.

2.2.5. Digital money

As outlined above, money has already undergone substantial transformations. Modern money, whether in the form of fiat money, coins or digital money in the savings account, holds an interesting paradox. Contrary to its historical forms, today's money lacks (substantial) intrinsic value. Instead, it is based on the trust in financial institutions and the state to guarantee its value and on modern technology to prevent fraud. Deposit money, the funds held in bank accounts, is the predominant form nowadays. It highlights the interplay between trust and technology, as it exists purely as digital entries in banks' ledgers and is transferred electronically. However, its economic value remains contingent on the confidence in the banking system (Pichler et al., 2018, p. 23ff.). Regulations, institutions and the state as a lender of last resort usually support this trust, ensuring that deposit money remains secure. Since the foundation of the Bank of England, the banking system has grown substantially, with central banks existing in virtually every Western country. Through monetary and fiscal policies, central banks aim to stabilize various economic factors, e.g. GDP growth, unemployment, price level stability or inflation, and the such. This monetary system is prevalent in most industrialized economies and can be traced back to the origin of the Bank of England. In essence, modern money's value is not derived from gold or silver but from trust and technology. Confidence in the institutions that issue the money and the technological safeguards that defend it define its value (Weber, 2018, p. 34ff.). Until today, there is a common misconception about how money (as deposit money) is created and about the role of central banks in our banking system.

Many textbooks still draw the picture of how banks merely act as financial intermediaries between savers and lenders, thus easing transactions. Some people put money in their savings accounts, and others would like to invest via credits and, therefore, lend said money. In this anecdote, a bank simply operates as an intermediary, transferring the money from A to B. Another misconception is that central banks could directly influence or control the money supply through central bank loans. Contrary to popular belief, money creation occurs when commercial banks issue loans. When a bank extends a loan, it generates a corresponding deposit in the borrower's account, effectively introducing new money into the system. Hence, this loan represents an asset from the bank's point of view and a liability from the view of the borrower. While banks create money through lending, they cannot do so arbitrarily. They have to adhere to certain limitations and regulations. In normal times, central banks implement some monetary policy by adjusting interest rates. In exceptional situations, such as when interest rates are close to zero, but an economy still faces recessionary tendencies due to a lack of economic activity, central banks might utilize quantitative easing (QE) to directly increase the money supply by purchasing assets or government bonds. If private and public sectors' aggregate activities do not foster investments, QE might guarantee the necessary liquidity to stimulate growth (McLeay et al., 2014). It is now widely agreed upon that the significant growth in finance prior to the financial crisis in 2007-08 strongly accelerated the gap between the financial and the real economy, which finally collapsed and resulted in said crisis. This acceleration was facilitated by the significant extent to which private consumption could be financed through the money creation by private banks, ultimately contributing to the creation of extensive economic bubbles (McLeay et al., 2014; Wullweber, 2021).

2.3. Cryptocurrencies

> "Each of these incarnations of money[13] has evolved to meet changing human needs surrounding the core functions of currencies. In this respect, currencies are not only instruments that facilitate economic activity but also currency is a technology of money that makes commitments between actors credible. As the technological capabilities of society evolve, and as social needs regarding the insurance of promises among actors change, the technology of money changes accordingly." (Marple, 2021, p. 439)

Currency basically depicts a promise between agents for the exchange of commodities.

[13] Ranging from shells to various metals, and eventually to today's paper currencies, money has taken a wide variety of physical forms. (Marple, 2021, p. 439)

The particular (physical) form of money is secondary as long as it is universally agreed upon. As outlined above, many materials have been used as money throughout history, with their physical forms varying greatly. However, two crude facts are inherent to all of them: the development of currencies is shaped by both technological advances and power structures. Hence, Bitcoin (BTC) and other cryptocurrencies are better understood within this scope (Marple, 2021, p. 439ff.). Kostakis and Giotitsas argue in the following way: The abandonment of the gold standard in 1971 enabled a more credit-oriented approach to money, which was necessary for financing the growing rate of the capitalist system. While this approach satisfied the ever-growing demand for financial liquidity, its unregulated framework ultimately led to the financial crisis in 2008 (Kostakis & Giotitsas, 2015, p. 432). With this background in mind, cryptocurrencies must be viewed as a response to the financial crisis. BTC was constructed to overcome the need for financial intermediaries, or in other words, an economic world without regulation executed by central and commercial banks (Marple, 2021, p. 439ff.).

2.3.1. Bitcoin

Bitcoin was first introduced in 2008 by an individual or a group under the pseudonym Satoshi Nakamoto. It represents a revolutionary peer-to-peer electronic cash system. Its core objective is to facilitate direct online transactions without the need for intermediaries like banks. The system's hallmark innovation is its ability to address the double-spending problem[14], a critical concern in digital currency, by utilizing a combination of digital signatures and a distributed peer-to-peer network. Transactions within the Bitcoin network are meticulously recorded in a public and immutable ledger called the blockchain. This ledger ensures that each cryptocurrency unit cannot be spent more than once, thereby ensuring the system's integrity. The process of maintaining this ledger involves "miners" who validate and add transactions to the blockchain. These miners are incentivized with new Bitcoins and transaction fees for their computational efforts in creating blocks. Obtaining Bitcoins involves mining, exchange, or trade of goods and services. Bitcoin's market-driven value leads to strong volatility (see Figure 2.2). As Bitcoin has no inherent value, it is only valuable as long as people agree to use it. The network's unique architecture ensures decentralization, enabling participants, known as nodes, to freely join or leave the network. Transactions and blocks are broadcasted across the network on a best-effort basis, creating a robust and secure environment. The network's decentralized nature also means that no central authority controls the issuance or supply of Bitcoins, and

[14] The double-spending problem is the risk and challenge of a digital currency being spent more than once.

the system is designed to cap the total number of Bitcoins at 21 million units. The cornerstone of Bitcoin's security lies in its "proof-of-work" concept, where miners compete to solve complex mathematical puzzles to validate transactions and create new blocks. This process ensures the trustworthiness of the blockchain by making it computationally expensive to alter historical records. Honest miners, who make up the majority of the network's computational power, have the economic incentive to maintain the integrity of the system, as dishonest behaviour would lead to a loss of rewards (Kostakis & Giotitsas, 2015; Nakamoto, 2008; Pichler et al., 2018).

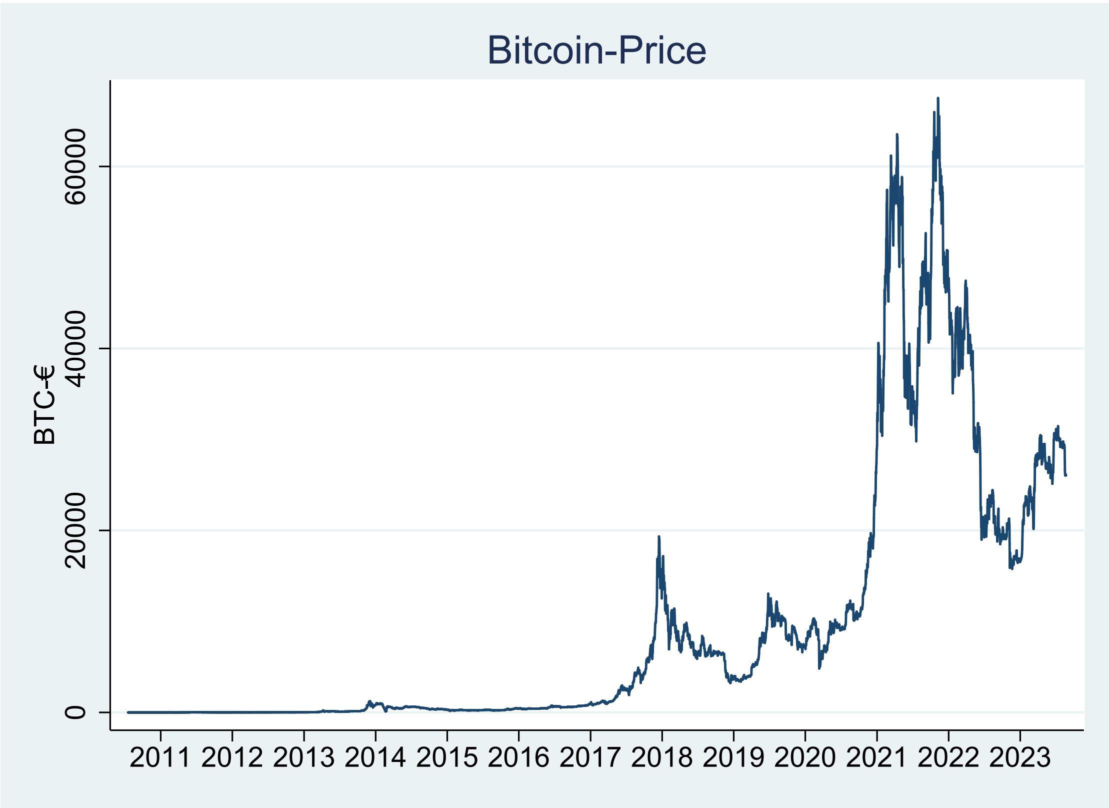

Figure 2.2.: Development of Bitcoin prices

Even though the white paper was already introduced in 2008, public interest in it only began to rise in 2013 for a number of reasons. Several external circumstances directed interest and public attention towards the potential advantages of employing blockchain technologies that were thought independent of financial institutions and governments. These circumstances included financial uncertainties in the eurozone,

technical malfunctions at prominent banks causing customers to be unable to access their funds, and the confirmation that contentious central bank QE initiatives would be prolonged far beyond their initial emergency response intent to the 2007-08 worldwide financial crisis (Campbell-Verduyn, 2018, p. 2). The increased interest in Bitcoin is evident in Figure 2.2, as the Bitcoin prices started to rise significantly from 2013 onwards, whereas they had remained close to zero before.
Bitcoin has, of course, been criticized from different angles. While experiments with new (financial) technologies are neither a novelty nor do they automatically increase inequality, they tend to attract excess finance capital investments, that in turn might create bubbles rather than fuelling the real economy (Kostakis & Giotitsas, 2015, p. 432). According to this notion, one can argue that BTC (and other cryptocoins) are digital commodities rather than digital currencies. A commodity becomes money only if it unites two functions: the standard of value and the medium of circulation. BTC mining gives the illusion of bringing new wealth into existence since it creates no corresponding liability (contrary to the issuance of money or financial assets), thus the notion of "digital gold". However, according to the labour theory of value, one can argue that BTC merely redistributes already existing value produced: It transfers value from the productive sectors of the global real economy but does not create new value, as only living, direct labour originates new value-added and the direct labour input in BTC is negligible. In this thought of view, Bitcoin might contribute to increasing global inequality (Rotta & Paraná, 2022). Bitcoin's fixed supply is considered a notable strength as it has deflationary tendencies. When it reaches its maximum limit, its value is prone to surge dramatically. Due to its high volatility, most companies are hesitant to accept BTC as payment. Early adopters and those with high-powered computational resources possess a distinct advantage over other users. The concentration of coins among a selected few investors[15] intensifies the risk of price instability, either through intentional retention or strategic trading of substantial amounts to influence its valuation (Kostakis & Giotitsas, 2015, p. 35f.). Probably the most severe critique of BTC, especially in times of climate warming, is its substantial energy consumption. Bitcoin is based on cryptographic puzzles, as solving these requires a significant amount of computational power; BTC has a considerable energy footprint per construction. The exact calculation of its energy consumption is impossible and varies permanently because it depends on the quality of the used GPUs. However, as the quantity of coins increases, the ledger becomes longer, and more computational power is needed, hence a tendency towards continuously higher energy consumption. In 2018, it

[15]The top 100 bitcoin wallets possess currently 14.7% of total Bitcoins mined (Information from (Bitinfocharts, 2023), accessed 24.08.2023).

was estimated that its energy consumption would soon be greater than aggregated energy generated by the whole world's solar panels (Eich, 2019, p. 95f.).

2.3.2. Similarities to Gold

Cryptocurrencies, especially Bitcoin, are often compared to gold due to their shared common features. Some of these similarities are evident. For instance, limited availability is a characteristic both gold and Bitcoin possess. There is only a finite amount of gold on Earth, and the number of Bitcoins is capped at 21 million. Neither gold nor Bitcoin is controlled by a central authority or government. They are decentralized assets supported by a distributed network of participants. Both assets are scarce, enhancing their appeal as stores of value. Gold's scarcity arises from its limited availability on Earth, while Bitcoin's scarcity is defined by its algorithm and limited supply. Both gold and Bitcoin are frequently perceived as hedges against inflation. Their limited availability can help preserve their value compared to fiat currencies, which are susceptible to inflation. Furthermore, both assets can maintain their value over extended periods. Gold has preserved its value over centuries, if not millennia, while Bitcoin has experienced significant value appreciation in its relatively short history—though it has also seen significant value depreciation. Investors regard both gold and Bitcoin as alternative asset classes that can be included in investment portfolios for diversification alongside traditional assets. Moreover, both gold and Bitcoin rely on people's trust and belief in their value. They do not possess intrinsic value[16] in the conventional sense, but are deemed valuable due to people's faith in them. Neither gold nor Bitcoin directly provide yield, and their usage as currency is limited. Gold and Bitcoin are also divisible into smaller units, facilitating transactions. In the case of Bitcoin, the terminology of precious metals was adopted, as the process of creating new Bitcoins is referred to as "mining a coin." A further deliberate similarity or approximation to gold is the Bitcoin logo, a golden coin featuring the "B" logo. However, scholars do not unanimously agree on whether Bitcoin being referred to as "digital gold" represents much more than a popular narrative or not (Baur & Hoang, 2021; Klein et al., 2018; L. Smales, 2019). Nonetheless, it is a widespread narrative that is broadcasted in a wide variety of different newspapers.[17]

[16] Except for gold, but not to the extent it is traded for.

[17] See for example (Bathija, 2021; Cuthbertson, 2023; Kuhn, 2021; Laboure, 2023; Reuters Staff, 2021; Zigah, 2020).

2.3.3. Other cryptocurrencies

Much like Bitcoin, other cryptocurrencies are digital currencies built on blockchain technology. These digital assets enable users to conduct transactions securely and in a decentralized manner, bypassing traditional financial intermediaries such as banks. Similar to Bitcoin, other cryptocurrencies are decentralized, meaning they are not controlled by a central authority or government. Instead, they are secured by a distributed network of computers known as a blockchain. Some of the most well-known alternatives to Bitcoin include Ethereum, Ripple (XRP), Litecoin, and Cardano. Each of these cryptocurrencies has its own unique features and use cases, contributing to a growing digital economy with the potential to reshape how assets and value are stored and transferred. The most well-known alternative cryptocurrency is Ethereum, although it lags far behind Bitcoin in terms of maximum prices and market capitalization.
Notwithstanding, it has achieved something significant: the transition from proof-of-work (as in Bitcoin) to proof-of-stake, thereby significantly reducing energy consumption. Proof-of-stake is often seen as a more environmentally friendly alternative to proof-of-work because it eliminates the competition for solving complex mathematical puzzles that consume a significant amount of energy (De Vries, 2023; Temperini & Corsi, 2023). Cardano, ETH (Ethereum), Solana, and XRP (Ripple) are other coins included in the analysis.

2.4. Literature review

Amidst recent economic uncertainties and monetary fluctuations, the pursuit of dependable inflation hedges has become increasingly significant, capturing the attention of both investors and policymakers. Given the primary objective of this thesis, which is to assess the effectiveness of two distinct asset classes, namely gold and cryptocurrencies, it is pertinent to review the existing literature on this subject. This section aims to compare various approaches employed in analysing this pivotal topic and summarise the distinctive findings, thus providing a concise overview of this expansive field of research that yields, to some extent, contradicting results.

Regarding gold, two essential points become evident when comparing the extensive existing literature on the subject:
1. Significant geographical differences make speaking broadly about gold's inflation-hedging properties challenging.

2. There are substantial differences between short-term and long-term protection against inflation.

Kavir Naidoo and Faeezah Peerbhai (2015), for example, studied gold as a potential inflation-hedge in the South African context from 2000-2014 with monthly data. Statistical testing was conducted for short-term and long-term analyses, using OLS regressions for the short run and Johansen's Cointegration for the long run. Additionally, inflation was decomposed into actual, expected, and unexpected inflation. While they find ambivalent results in the short-run, they ascribe gold to a reliable long-term inflation-hedging potential. Noteworthy, they provide an overview of research in the international context of gold's inflation-hedging properties (Naidoo & Peerbhai, 2015). Mohd Fahmi Ghazali, Hooi Hooi Lean and Zakaria Bahari examined Malaysia between 2001 and 2011 via OLS-regression models and found no statistically significant results (Ghazali et al., 2012). Joscha Beckmann and Robert Czudaj (2013) examine whether gold can effectively hedge against inflation in four major economies: the USA, the UK, the Euro area, and Japan. They use monthly data from 1970 to 2011 and employ a Markov-switching vector error correction model (MS-VECM) approach to investigate. This approach allows for non-linearity and distinguishes between long-term and time-varying short-term dynamics. Their main results are: 1) Gold partially hedges future inflation in the long run, with varying degrees of effectiveness across the four economies. It appears more effective for the USA and the UK than Japan and the Euro area. However, gold does not provide adequate protection during periods without price adjustment. 2) The adjustment of general price levels exhibits regime dependence, indicating that the utility of gold as an inflation hedge depends on the economic context (Beckmann & Czudaj, 2013).
Georgios Bampinas and Theodore Panagiotidis (2015) employ both time-invariant and time-varying co-integration analyses to examine the long-run hedging ability of gold and silver prices against various consumer price indices (CPI) in the US and the UK over more than 200 years, using annual data. The main findings indicate that gold exhibits strong long-term hedging ability against inflation, with average beta coefficients above one, particularly in the US. Additionally, the study suggests that silver can serve as an inflation hedge in the UK when considering time-varying co-integration (Bampinas & Panagiotidis, 2015).

Its attributes as a safe-haven are much less contentious than the inflation-hedging properties of gold. However, this may also be attributed to the need for more research on this aspect. Two studies by Dirk Baur and Thomas McDermott (2010, 2016) are integrated

into this field, where they investigate the safe-haven properties of gold. While gold carries a higher risk than alternatives like US government bonds, for example, empirical analysis demonstrates gold's strong safe-haven characteristics, notably during critical events like September 11, 2001, and the financial crisis of 2007-08. Additionally, in the context of its role as a safe-haven, a 30-year analysis spanning from 1979 to 2009 reveals that gold serves as both a hedge and a safe-haven for major European stock markets and the US. However, it does not exhibit safe-haven properties for specific countries like Australia, Canada, Japan and large emerging markets such as the BRIC countries. This distinction highlights gold's varying degrees of effectiveness as a safe-haven asset depending on the specific market conditions. They find that safe-haven assets, including gold, do not exacerbate crises through negative feedback effects (Baur & Lucey, 2010; Baur & McDermott, 2016).
In the case of Bitcoin, the results are less conclusive. While there are indications that Bitcoin can function as a safe-haven, most interpret the findings to suggest that Bitcoin is more commonly used as a speculative investment and caution against engaging in investment behaviour without careful consideration and risk assessment[18] (Baur et al., 2018; L. Smales, 2019), a view that is also confirmed by Eng-Tuck Cheah and John Fry, who conclude that Bitcoin is prone to speculative bubbles (Cheah & Fry, 2015).
Dirk G. Baur and Lai Hoang (2021) wanted to shed light on the notion of Bitcoin as new, digital gold and find negligible results. They find a near-zero correlation via different approaches and timelines, contradicting the claimed similarity between the two assets. However, they argue there are two possible explanations for this finding: 1) Substitution Effect: Bitcoin and gold might be treated as substitutes rather than similar assets. 2) Catching-Up Effect: Instead of trading gold for Bitcoin, investors might hold on to their gold assets and additionally invest in Bitcoin (Baur & Hoang, 2021).
Using weekly data and a VAR model, Sangyup Choi and Junhyeok Shin (2022) found that Bitcoin served during COVID-19 as an effective hedge against inflation or inflation expectations, similar to gold. However, it differs from gold's quality as a safe-haven during financial uncertainty shocks. Also, they stress that they examined only a short period, which might not be significant for more prolonged periods (Choi & Shin, 2022).
Konstantinos Gkillas and François Longin (2019) employ a multivariate extreme value theory and firstly confirm gold's status as a safe-haven asset but also find indications this might hold true for Bitcoin (Gkillas & Longin, 2019). Smales (2022) examines the inflation-hedging properties of both gold and cryptocurrencies within the US, using daily data and an OLS-model. He finds an initial positive relationship between cryptocurrency returns and short-term inflation expectations; this association becomes insignificant when

[18]Nonetheless, this holds equally true for gold as well.

actual inflation or inflation expectations exceed two %. In contrast, gold demonstrates more consistent and reliable hedging properties against changes in inflation, making it a preferred choice for investors seeking inflation protection (L. A. Smales, 2022). Mykola Pinchuk (2021) examines the response of significant cryptocurrencies, particularly Bitcoin, to macroeconomic news announcements (MNA). He finds that while most cryptocurrencies do not react significantly to major MNAs, Bitcoin responds negatively to inflation surprises, which contradicts the common belief that Bitcoin can serve as an effective hedge against inflation. Further, it is ruled out that its negative response results from interest changes. Instead, he concludes that Bitcoin is highly dependent on shifts in consumption-savings decisions, which, in turn, are highly influenced by rising inflation, i.e., a decrease in disposable income negatively affects BTC prices (Pinchuk, 2021).
In concluding this chapter, it is evident that both gold and Bitcoin, as subjects of extensive research, showcase a notable variability in results, with the quality of the findings particularly affected by the temporal and geographical context of the study. Regarding gold, the efficacy of its inflation-hedging properties is contingent upon the duration of the study period. While, on average, the inflation-hedging properties of gold increase with more extended examination periods, more recent research tends to fail to establish an unambiguous link between gold and inflation-hedging potential (Arnold & Auer, 2015; Phochanachan et al., 2022). Similarly, this trend is mirrored in studies focused on Bitcoin and cryptocurrencies in general (while the vast majority is centred around Bitcoin). However, due to their relatively short existence in the financial landscape, investigations are limited to shorter periods, making comprehensive assessments of their long-term inflation-hedging potential challenging at this point and simultaneously underscoring the future research potential in this area.

3. Empiric part

In this chapter, the empirical analysis will be presented; it is structured as follows. First, the method will be introduced, including the empirical model, followed by a description of the data sources used and an overview of descriptive statistics. Finally, the empirical results will be presented, followed by the final results and concluding with a discussion of the findings.

3.1. Method

In the following, the method will be outlined; this includes the specifics of the model, details on the expected inflation rate that is used in this analysis and a short description of the data sources.

3.1.1. Model

In order to provide an answer to the research question regarding the inflation-hedging properties of gold and cryptocurrencies, the following OLS model with lags is applied:

$$R_t = \beta_0 + \beta_1 \%\Delta EI_t + \sum_{j=2-6} \beta_{jt} Control_{jt} + \beta_6 R_{t-1} + \epsilon_t \tag{3.1}$$

Where each parameter is specified as follows:

- $R_t = 100 \cdot \log\left(\frac{P_t}{P_{t-1}}\right)$, is the return of gold and cryptocurrencies in time t calcuated from prices in time t and $(t-1)$, respectively[1]
- β_0 is the intercept
- β_1 is the parameter of interest as $\%\Delta EI_t$ is the percentage change in expected inflation from time $(t-1)$ to t

[1] For a quick recap on the interpretation of log-linear regression output, see, for example, Benoit, 2011 or Palmer, 2011.

- β_{jt} and $Control_{jt}$ are coefficients and control variables, respectively, to correct for other relevant economic and financial factors, specifically:
  - VSTOXX, is an implied volatility index
  - EPU, European Policy Uncertainty
  - Term Premium, difference between the 5- and 10-year treasury yield
  - ESI, European Sentiment Indicator
  - DAX index
- R_{t-1} is the lag of the return on gold/cryptocurrencies, hence the return in $(t-1)$
- ϵ_t is an error term

The single variables will be explained in more detail below. By taking into account Equation 2.3 and 2.4, the model can be extended to incorporate both anticipated and unexpected inflation rates, thus being closer to the original formula based on Fama and Schwert:

$$R_t = \beta_0 + \beta_1 E_{t-1}(\pi_t) + \beta_2 \Big[\pi_t - E_{t-1}(\pi_t)\Big] + \sum_{j=2-5} \beta_{jt} + \beta_6 R_{t-1} + \epsilon_t \tag{3.2}$$

3.1.2. Expected inflation: Break-even inflation rates

As outlined in chapters 2.1.5, 2.1.4 and 2.1.6, some form of measurement of expected inflation is necessary to examine the inflation-hedging properties of assets in detail. Since the assets examined in this analysis are gold and cryptocurrencies, which are easily tradeable and volatile, using measurements of expected inflation that rely on surveys and expert forecasts is not feasible. These methods are not conducted frequently enough, potentially resulting in the loss of important information between data points. Consequently, in this thesis, a market-based measure is employed, known as the break-even inflation rate (BREIR), which can be summarized as follows:

> "One closely followed indicator is the difference between yields on nominal Treasury securities and Treasury inflation protected securities (TIPS) for a given maturity, also known as breakeven inflation given that it is the level of inflation that makes investors indifferent between both kinds of securities." (Baumeister, 2023, p. 428)

In its literal sense, "break-even" refers to the exact point between two alternatives where indifference occurs. Investors usually have a strong financial interest in accurate inflation pricing, which makes the break-even inflation rate a more reliable indicator of inflation expectations than survey-based measures. Break-even analysis assesses relative performance over a horizon shorter than bond maturity. For illustration, the break-even inflation rate (BREIR) formula[2] becomes useful:

$$BREIR_t^n = y_t^n - r_t^n \tag{3.3}$$

This formula calculates the difference between the nominal interest rate y at time t and maturity n and the real interest rate r (i.e. inflation-linked), also at time t and maturity n, the difference equals the BREIR. In other words, if the actual inflation rate equals the expected BREIR, an investor is indifferent between a nominal and an inflation-linked bond. The BREIR makes an investor indifferent between nominal and inflation-linked bonds.

Treasury inflation-protected securities (TIPS) are bonds indexed to inflation and issued by the US government. There is no European-wide counterpart to TIPS, which would be inflation-linked bonds issued by the ECB/EU and linked to the HICP. However, most Euro-states issue their own inflation-linked bonds linked to their national inflation rate. In Figure 3.1 above, the break-even inflation rates for different government bonds of Germany are depicted next to Germany's HICP in the period from 2012 to 2023.
Before 2021, the inflation rate, as denoted by the HICP, generally shows little change over time. Most of the time, it remained around ± 2 % (on average), largely in line with the ECB's target inflation rate. At times, however, it came very close to 0 and even became negative for short periods of time. Overall, it shows past difficulties of the ECB reaching its goal of a constantly trending 2 % inflation rate. This can be directly linked to the ECB's longstanding low-interest-rate policy aimed at promoting investments to stimulate the economy and prevent slipping into deflationary pressures. Interestingly, inflation rates experienced a brief uptick before the onset of the 2020 pandemic. At the beginning of and during the earlier periods of the pandemic, inflation steadily decreased, likely due to economic uncertainty and the temporary halt in aggregate demand, as both firms and households tended to postpone investments that were not urgent. This can be linked to a general decline in prices. Inflation even became negative during the second half of 2020.

[2] The formula put into words: "The comparison between the nominal and real term structure gives the inflation compensation requested by investors to hold standard nominal bonds." (Pericoli, 2012, p. 8)

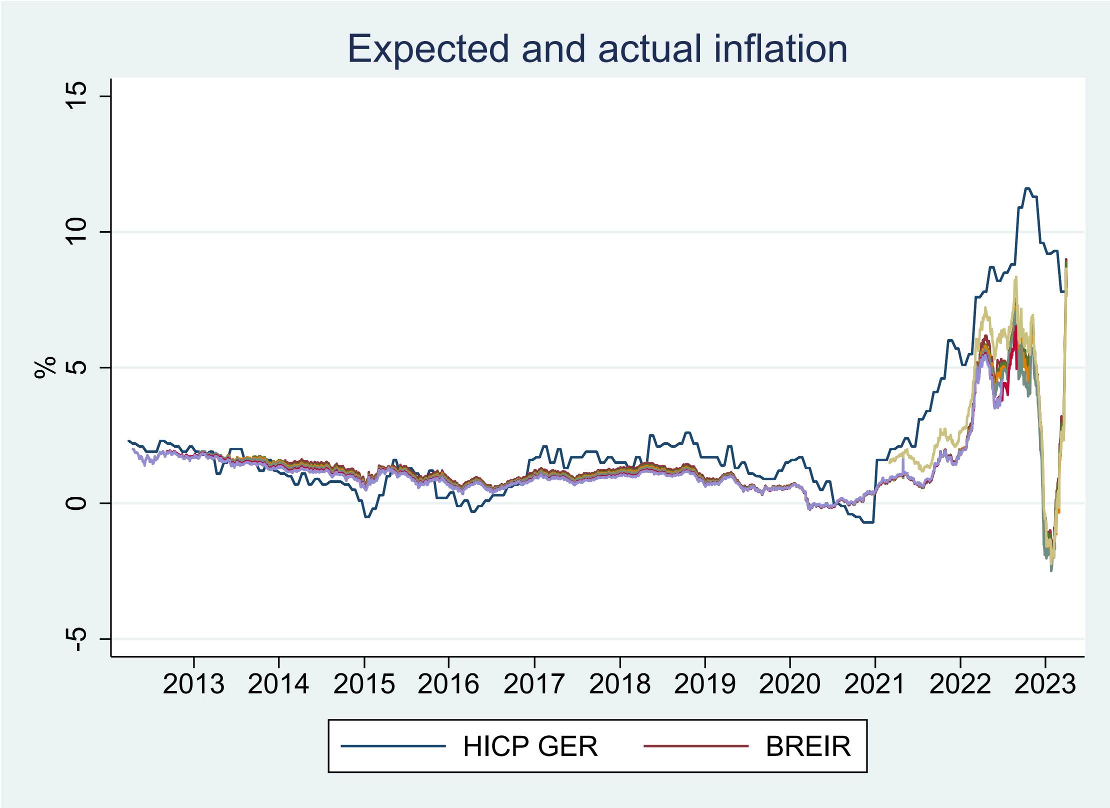

Figure 3.1.: Break-even inflation rate and actual inflation rate in Germany

At the beginning of 2021, however, inflation suddenly surged by several percentage points. This challenges the widely circulated argument that the Ukraine-Russian war and the associated energy crisis were the main triggers for high inflation. It is more likely that price increases were driven by global supply shortages and, in part, a correction from the low prices seen at the beginning of the pandemic-induced uncertainty. It is beyond doubt that the sharply increased energy prices, starting in 2022, further fueled inflation. However, the timeline shows that surging inflation cannot be attributed simply to energy prices.

When looking at the break-even inflation rates, it becomes evident that they have very closely tracked the actual inflation rate throughout the entire period of moderate inflation. However, there are minor fluctuations in the opposite direction, for example, in mid-2016. Sometimes, the BREIRs are a lag- and sometimes a lead variable to the actual inflation rate. So, they behave very smoothly, with the BREIRs having fewer fluctuations but following a smoother trend than actual inflation rates. However, the co-movement seemed to last until 2021; it becomes evident that the financial markets did not anticipate the sudden and significant increase in inflation. If 2021 is seen as a cut-off point, BREIRs then follow for a short period, a very similar trend to what had been observed in previous years, but the abrupt rise in inflation - that took place suddenly in 2021 - was not foreseen. Only after 2022 do financial markets seem to have adjusted, which is evident in a sharp rise in BREIRs, even though they did not reach the actual level of inflation. So, some distortions between anticipation and occurrence become evident in the final phase of the examined period. Nonetheless, by visually comparing the German HICP with BREIRs as computed from German bonds, the expected inflation rate appears to be a very valid instrument for inflation.

3.1.3. Data

This chapter provides an overview of the diverse data sources that constitute the foundation of the analysis. The data used in this study has been meticulously gathered from a variety of reputable sources, focusing on primary sources. The situation in Europe, characterised by many diverse countries and financial markets, posed an intricate scenario. Therefore, a selection from a wide variety of specific sources was necessary. Moreover, the fact that exchange rates involving gold and cryptocurrencies are primarily quoted in US dollars introduces additional complexity in analysing the European case. This implies the added risk of exchange rate volatility between the US dollar and the Euro. An overview of different data sources is provided hereafter:

Inflation

Data for inflation was retrieved from Eurostat: The Harmonised Index of Consumer Prices (HICP), with the online data code PRC_HICP_MIDX and the year 2005 as reference period (2005 = 100). As mentioned above, the HICP is released on a monthly basis. Data was retrieved for the whole eurozone, but also for Germany and other countries, in order to grasp a fuller understanding. For further details, see the documentation at Eurostat: (Eurostat, 2023b).

BREIR

As mentioned above, there exists no European counterpart to the US TIPS. Therefore, data on specific European countries' bonds had to be consulted. Data on bonds from

various statistical sources and national central banks was utilized to calculate the break-even inflation rate, including Spain, France, Germany, Italy, the Netherlands, and Austria. However, challenges such as general and public data availability and the availability of inflation-indexed bonds and nominal bonds with similar maturity and issuance dates complicated the process. Given that the data situation in Germany was relatively robust and Germany is considered one of the key economies in Europe, particularly due to its substantial manufacturing sector, the decision was made to select German bonds as the instrument for the entire currency zone. Also, in comparison, All bond data was selected from the German Bundesbank, where both data on inflation-linked and nominal bonds can be retrieved. To access data on inflation-indexed and nominal bonds inclusive yields, go to (Bundesbank, 2023) and follow the following path: statistics - time series data - Money and capital markets - Interest Rates and Yields - Prices and Yields of listed Federal securities (per ISIN) - Yields.
An overview of the bonds that were used for calculating the break-even inflation rates is provided in the Appendix in Table A.1, where the bonds are listed via their ISIN[3].

Gold and Cryptocurrencies

Data on the daily prices were retrieved from two sources to calculate the return on gold and cryptocurrencies. On the one hand, gold prices were selected from the German Bundesbank, where the price of 1 ounce of fine gold in EUR is quoted during the morning fixing. For Figure 2.1, gold prices expressed in USD were used, as more historical data was available in USD. All data on cryptocurrencies and also data on gold futures were retrieved from (Investing, 2023b), where historical data on prices (Price, Open, High, Low) is available. Here, in this analysis, closing prices were used. An essential distinction between gold and cryptocurrencies is that gold can be traded only during weekdays, whereas cryptocurrencies can usually also be traded during weekends and holidays. In order to align the time-series, data points for which no data on gold prices were available were excluded from the analysis.

VSTOXX

The VSTOXX (EURO STOXX 50 Volatility Index) measures expected volatility in the EURO STOXX 50 Index, representing the performance of the top 50 companies in the eurozone. The VSTOXX quantifies the anticipated future volatility of the EURO STOXX 50 Index. While historical volatility is based on past price movements, the VSTOXX is

[3]International Securities Identification Number

based on implied volatility that is derived from option prices and hence expresses expected volatility. It serves as an indicator of market volatility and is applied by traders and investors for risk assessment and trading decisions (Qontigo, 2023c, p. 28). Data can be retrieved here: (Qontigo, 2023b)

Economic Policy Uncertainty

The Economic Policy Uncertainty (EPU) Index measures policy-related economic uncertainty; it was initially constructed based on the U.S., but it has been adopted for many Western economies, including Europe and several European states. The EPU is based on newspaper articles from two newspapers per European country. For example, Le Monde and Le Figaro are considered for France, Handelsblatt and Frankfurter Allgemeine Zeitung for Germany. The index counts articles containing terms like "uncertain" or "uncertainty," "economic" or "economy," and one or more policy-related terms. These searches are conducted in the native language of the newspaper. The raw EPU count is scaled by the number of articles in the same newspaper and month. Each newspaper-level monthly series is standardized to unit standard deviation before 2011. Country-level and European EPU indexes were normalized to a mean of 100 before 2011. The counts from the two newspapers in each country are averaged for country-level indexes. For the European-wide EPU index, counts from all 10 European newspapers are equally averaged. It provides valuable insights into how policy-related events and discussions impact economic uncertainty in the region (Baker et al., 2016). For further detail, see the *policyuncertainty* homepage. Data can be retrieved here: (Baker et al., 2023)

Term Premium

Data for calculating the Term Premium was retrieved from the ECB's website. The term premium is a term that refers to the additional yield that investors demand from long-term bonds compared to short-term bonds to compensate for the higher risk and uncertainty associated with longer maturities. Essentially, the Term Premium is the difference between the yield of a long-term bond and the expected short-term yield that investors would anticipate if they were to invest their money in short-term bonds and continuously reinvest. This premium (the difference) can be either positive or negative:

$$Term - Premium = yield\ on\ long\ term\ bond - yield\ on\ short\ term\ bond$$

A positive Term premium correlates to investors demanding a higher yield on long-term

bonds to compensate for the additional risk and uncertainty due to the longer maturity. Various reasons are relevant, e.g., expected interest hikes, inflation risks, or economic uncertainty.
A negative Term premium means investors are willing to accept a lower yield on long-term bonds than they could achieve with short-term bonds. This may occur when investors seek safe-haven investments, as in relatively stable long-term bonds, or during times of long-term low central bank interest rates. Therefore, the Term premium can indicate overall market sentiment and economic outlook (Crump et al., 2023; Romanchuk, 2013). The financial market data, specifically yield curves for nominal bonds with varying maturity periods, was obtained from the following source: (ECB, 2023b). Specifically, bonds were used with 5 and 10 years of maturity, respectively.

Economic Sentiment Indicator

The Economic Sentiment Indicator (ESI) is an index that is calculated monthly on a selection of different questions on the basis of industry, services, retail trade, construction and consumer surveys. Data was retrieved from Eurostat, with the online data code $EI\_BSSI\_M\_R2$. The data source is the European Commission - Directorate-General for Economic and Financial Affairs (DG DCFIN). For more details, see (Eurostat, 2023a).

Interest rate

Daily data on the key interest rate was retrieved from the European Central Bank from the Statistical Data Warehouse. However, it is essential to note that the interest rates were kept consistently low for the majority of the study period, making them unsuitable as an explanatory variable, as the upward interest rate adjustments were only implemented towards the very end of the examined period; therefore they are not included in the final model. Nonetheless, interest rates could be a crucial elaboration in the aspect of inflation-hedging for future research. Data can be found here: (ECB, 2023a)

DAX

Data on DAX Futures was retrieved from (Investing, 2023a) and also from the Qontigo homepage, according to which DAX "tracks the performance of the 40 largest companies listed on the Regulated Market of Frankfurter Wertpapierbörse (FWB©, the Frankfurt Stock Exchange) that fulfil certain minimum quality and profitability requirements." (Qontigo, 2023a) Hence, the development of DAX is an appropriate instrument for the developments of the financial markets in Germany and Europe to some extent.

3.2. Descriptive statistics

The following section first undertakes the challenging task of visually comparing the price and return development of gold and cryptocurrencies. Subsequently, it provides a descriptive overview of the remaining statistical data and addresses issues related to time-series analysis, including auto-correlation and subsequent data transformations.

Visual representation of gold and cryptocurrency returns

Both Figure 3.2, Figure 3.3, and Figure 3.4 show the long-term price development of gold and cryptocurrencies. However, there are some important distinctions to mention. Since gold and cryptocurrencies (especially Bitcoin) vary significantly in absolute value and volatility, it is challenging to represent them together over time graphically. Therefore, the graphs exhibit some differences. In order to represent the relative value increase, a logarithmic presentation was chosen. All three graphs depict the logarithmic percentage change to some base day; however, the base day is not the same in all three but it will be explained in detail.

For gold, data was available from 1968, and to show a long-term trend, the whole period is depicted. As cryptocurrencies are very volatile (see, for example, Figure 2.2), it is not simply possible to compare daily prices for gold and cryptocurrencies while attempting to display trends. Therefore, logarithmic percentage differences relative to some base days were calculated; these visualise long-term growth trends. Data for gold goes as far back as 1968, when an ounce of gold was worth USD 38. For comparing the relative growth of gold with cryptocurrencies, however, it was impossible to choose the original base day of the cryptocurrencies, i.e. when they were created. All cryptocurrencies were worth basically nothing when they came into existence; hence, they show a substantial relative growth vis-a-vis their original base day (see Figure 3.3). In order to enable some form of comparison between cryptocurrencies and gold, they all have the same base day in terms of value, namely the day when they reached a value of €30. Their relative growth rates are then calculated in relation to this day. However, in total, Bitcoin, Ethereum, XRP, Cardano, and Solana should be compared here, but XRP and Cardano are not included in the first graph, as their values have not reached values of €30 or higher till today, therefore they are only included in the next graph.

When examining gold, it is evident that it has a long-term positive trend in growth, which is why it is often referred to as a long-term investment or even safe-haven asset and is associated with an inflation-hedge. Even though it is not depicted in the graph, it is important to note that gold did not experience significant growth before 1970; it remained

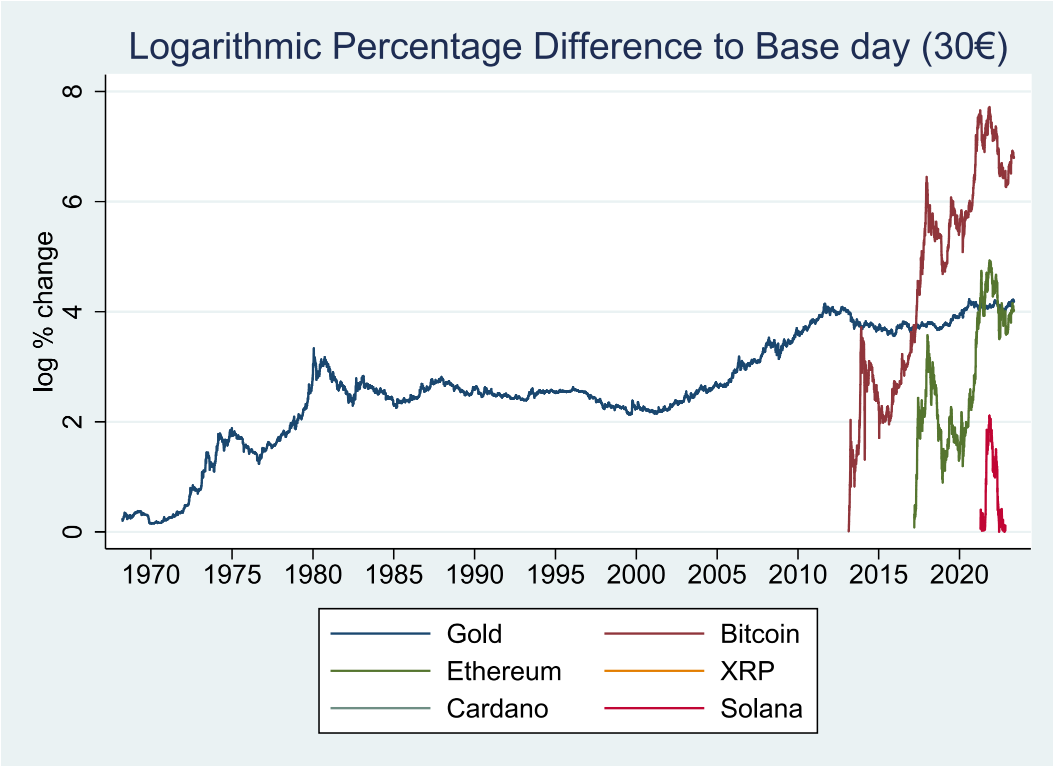

Figure 3.2.: Logarithmic difference vis-a-vis base day (30 Euro)

relatively stable before that period. However, that trend changed at the beginning of the 1970s when gold suddenly witnessed a significant increase in value, which coincided with the end of the gold standard. Gold then experienced strong growth until the early 1980s; this period was briefly interrupted in the mid-1970s due to the oil price shocks. After the 1980s, its growth flattened out somewhat and was relatively constant until the 2000s, but from then on, it experienced a rapid upward trajectory until 2013-14. Since then, it has remained relatively stable again. In summary, a long-term positive trend is evident despite periods of stagnation and occasional downturns.

Bitcoin was the first cryptocurrency to have reached a value of €30, followed by Ethereum and Solana. It is noteworthy that both Bitcoin and Ethereum, while they are still relatively young, at least in comparison to gold, experienced strong relative growth phases within a short period of time. Overall, Bitcoin and Ethereum exhibit very similar growth patterns, albeit with variations in timing and intensity, but their curves are highly similar. Figure 3.3 provides a clearer picture of cryptocurrencies' relative growth phases. It is important to note that in this figure, the relative logarithmic growth is not compared to the first

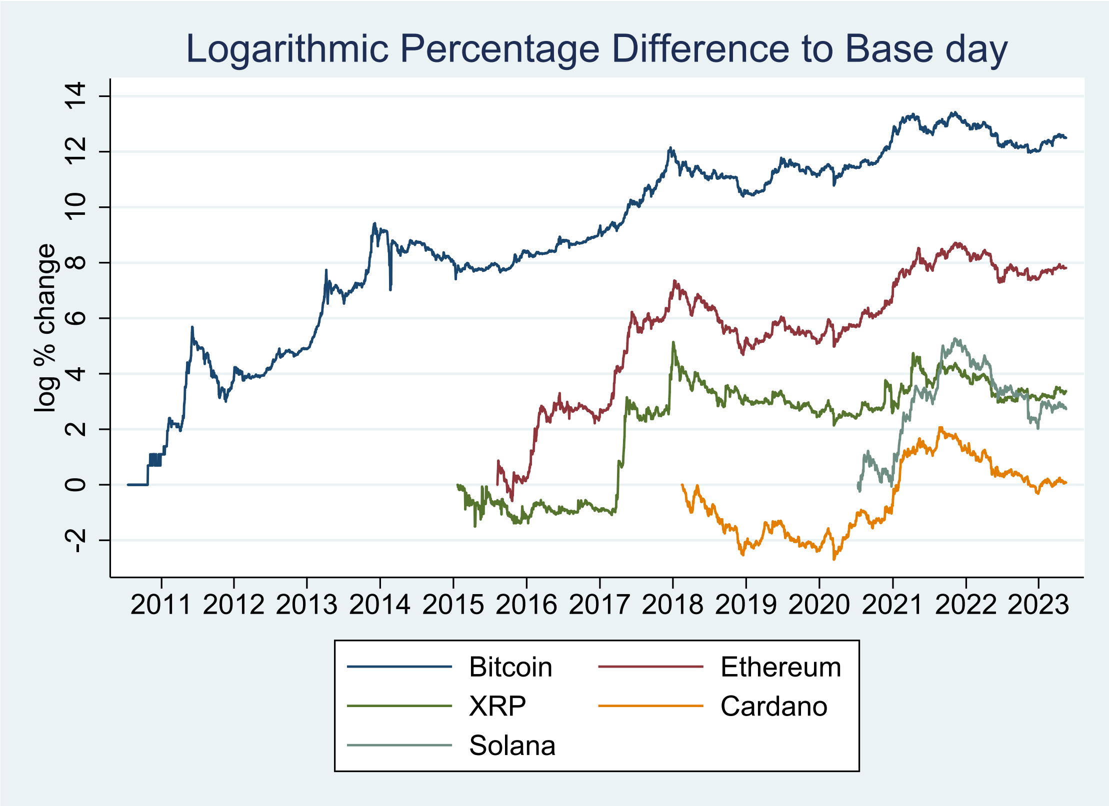

Figure 3.3.: Logarithmic difference vis-a-vis base day

day when the currency was worth €30, but rather to the first day for which data was available for each respective currency. Therefore, the base-day value is very low (close to 0) for all currencies, resulting in a significantly stronger relative growth compared to the previous graph. When considering logarithmic growth, it becomes apparent that most cryptocurrencies have experienced a significant increase in their early stages, but over time, their growth rates tapered off. Notably, Bitcoin, Ethereum and XRP show a significant co-movement behaviour, indicating a high correlation.

Figure 3.4 is constructed the same way as Figure 3.2 above, except that it includes the inflation rate from mid-2010 until mid-2023, displayed on the y-axis on the right. This graph only includes Bitcoin and Ethereum to provide a more precise presentation, as they are the two most significant cryptocurrencies. The logarithmic growth rates are again calculated relative to their respective base values of €30, allowing for a meaningful comparison to gold. This adjustment is necessary to prevent data compression and ensure informative visuals. Regarding inflation levels, they remained relatively stable

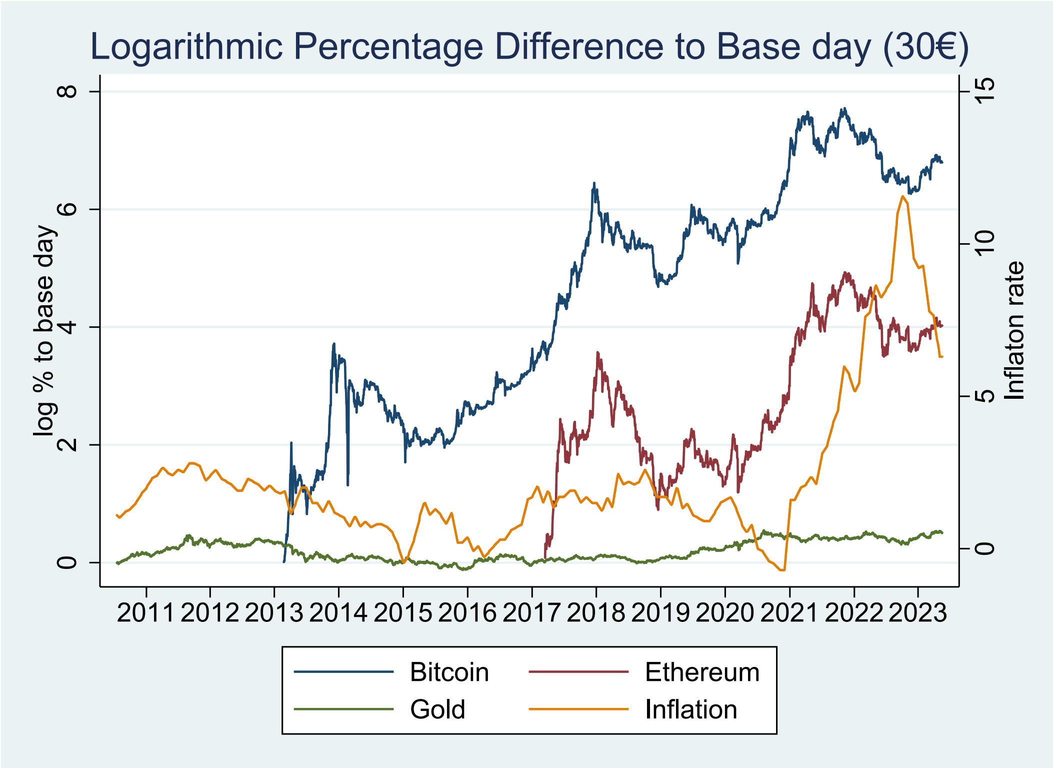

Figure 3.4.: Logarithmic difference vis-a-vis base day (30 Euro)/ Inflation

until 2020, with two exceptions in 2015 and 2016. Prior to and after these spikes, inflation rates remained relatively constant, typically staying below 2%. As shown above, gold experienced its most substantial growth rates before 2000, followed by a period of relatively stable growth. However, it showed renewed growth rates after 2019. Bitcoin and Ethereum exhibit periods in which their relative logarithmic growth closely aligns with inflation. This synchronicity is particularly pronounced after from 2021 onwards, notably for Ethereum, and during the short-term trend from 2017 to mid-2018. During this period, inflation appears to be a lagged variable in response to cryptocurrency prices. Gold also demonstrates periods of close co-movement, especially from 2011 to 2014. However, a key distinction is its significantly lower volatility compared to cryptocurrencies and its lesser sensitivity to changes in inflation.

Statistical representation of gold and cryptocurrency returns

Table 3.1 introduces the main variables of the analysis with a brief statistical description. The table is constructed in a way to interpret it intuitively. The left column shows the variable names and the top row shows the different indicators that are included in the table, namely the amount of observations, the minimum and maximum, the mean, standard deviation, median, skewness and kurtosis. The top panels give an overview of gold and cryptocurrency prices and on returns of gold and cryptocoins, respectively. Inflation is a critical factor that influences the purchasing power of assets over time. In this context, gold and cryptocurrencies have gained prominence as potential hedges against inflation. To examine this assumption and gain a deeper understanding of the behaviour of these assets, we explore various variables that play a crucial role in our analysis. The first panel shows some statistics on the different price levels. As gold is the oldest and has long existed prior to the starting date of the analysis, its minimum value is not near 0, in contrast to the cryptocurrencies. First, to illustrate the issue of exchange rates, both USD and Euro prices of gold were included. As the starting point of the analysis was chosen to include Bitcoin, as it is the oldest cryptocurrency, the number of observations of BTC matches gold. However, as shown visually in Figure 2.2, the absolute range of BTC prices exceeds all others by far, with a maximum value of Euro 67.527,90. It does so as well, however, in volatility, as indicated again in the graph above, by its lower mean relative to its maximum value and a drastically larger standard deviation compared to all other assets; also, its higher kurtosis indicates high volatility. While its mean is much higher than gold's, its median is lower. However, this stems from the fact that BTC was worth very little for several years.[4] The second largest cryptocurrency, both in volume and peak prices, is Ethereum. With a maximum value of Euro 4.150,40, it is far above gold. However, as indicated above and by its standard deviation, it is relatively volatile, similar to BTC. The remainder of the cryptocurrencies is relatively insignificant compared to gold, BTC and Ethereum, both in volume and price. The coin with the third highest price level is Solana, even though it is the youngest in the sample, as indicated by the lowest number of observations. Cardano and XRP show both a tiny range between their minimum and maximum, indicating no drastic speculative investment behaviour. Nonetheless, as already argued in length above, in comparing very distinct assets, the nominal prices are of little assistance in making meaningful comparisons. Therefore, the log-returns of the same assets are included. The assets were calculated as outlined above in the section on the base model.[5]

Return data provides insights into how assets evolve over time. BTC stands out here, as it exhibits the highest average return and standard deviation. This high volatility could indicate speculative trading activity rather than the indication of Bitcoin as a long-term

[4] BTC reached triple digits not earlier than 2013 and four digits not before 2017.

[5] $R_t = 100 \cdot \log\left(\frac{P_t}{P_{t-1}}\right)$

inflation hedge. In contrast, the returns of Cardano, ETH, and Solana appear more stable, potentially reflecting varying risk tolerance among investors. Skewness measures the asymmetry of the distribution; the kurtosis provides a picture of the tails where low values imply a higher density in the centre of the distribution than in the tails. A high

kurtosis then suggests a higher likelihood of extreme price swings. The last panel presents different inflation rates: the inflation rate for Germany (as the break-even inflation rates were calculated from German bonds), the inflation rate for the eurozone and then different break-even inflation rates. As already seen in Figure 3.1, all of the BREIR succumb to the maximum values of actual inflation rates and, hence, have lower mean and median values (with exemption from BREIR6). The different bond issuance dates explain why not all break-even rates have the same number of observations. The most pressing nuance here is that BREIRs have significantly lower minimum values than actual inflation, which stems simply from the fact that in the recent two years, inflation-linked bonds experienced a sudden sharp rise, which results in a temporarily negative break-even inflation rate.
Table 3.2 shows a correlation matrix between log returns on gold (EUR) and the cryptocurrencies in the sample. While Figures 3.2, 3.3 and 3.4 already show a strong indication of prevailing correlation between cryptocurrencies, there is one major difference regarding the calculation of returns. Above, returns were calculated in relation to some base day for visualising long-term growth trends. Here, as in the regression later as well, returns are calculated in relation to their prior day, hence depicting short-term trends.

The correlation matrix presented in Table 3.2 provides valuable insights into the relationships between the selected variables, which include Gold, BTC, Cardano, ETH, Solana, and XRP. In this context, two key observations can be made: Gold has virtually no correlation with cryptocurrencies; it correlates with BTC and ETH on a deficient level, 0.051 and 0.049, respectively ($p<0.05$). Nonetheless, this indicates they are moving in the same direction. However, in contrast to the cryptocurrencies, the relationship between gold and the coins seems negligible as all of the cryptocurrencies show (strong) correlation levels ($p<0.01$). BTC has a very strong relationship with Cardano, a similar one with ETH and Solana and a somewhat weaker yet still significant correlation with XRP. Cardano shows a significant positive correlation with both BTC and ETH. This suggests that changes in Cardano prices are associated with similar changes in BTC and ETH prices. Solana and XRP display relatively strong positive correlations with BTC, ETH, and Cardano, indicating a higher degree of co-movement between these cryptocurrencies.

Variable	N	Min	Max	Mean	Std. Dev.	Median	Skewness	Kurtosis
Price								
Gold	3241	871.96	1860.21	1242.9	252.73	1149.15	0.74	2.35
Gold USD	3241	1050.6	2061.50	1475.73	255.54	1374.75	0.4	1.77
BTC	3241	0.1	67 527.90	9065.11	14 531.16	931.7	1.97	6.1
Cardano	1334	0	2.50	0.42	0.52	0.15	1.64	5.05
ETH	1964	0.38	4150.40	750.46	966.13	249.29	1.49	4.32
Solana	701	1	248.42	51.86	59.14	30.6	1.52	4.34
XRP	2103	0	2.73	0.36	0.35	0.29	1.75	7.99
Return								
Gold	3241	91.32	106.21	100.03	0.9	100.01	−0.15	10.8
Gold USD	3241	91.47	107.03	100.02	0.96	100.02	−0.28	9.2
BTC	3241	42.79	436.75	100.68	9.17	100	16.28	568.79
Cardano	1327	60.23	133.13	100.23	6.72	99.88	0.51	6.61
ETH	1962	57.19	166.43	100.65	7.26	100.11	1.2	12.47
Solana	696	57.65	164.86	100.83	9.46	100.06	1.57	11.96
XRP	2102	36.92	255.33	100.67	10.89	99.94	4.15	47.02
log Return								
Gold	3241	−9.08	6.02	0.02	0.91	0.01	−0.29	11.39
Gold USD	3241	−8.91	6.79	0.02	0.96	0.02	−0.4	9.66
BTC	3241	−84.88	147.42	0.39	7.25	0	2.49	72.83
Cardano	1327	−50.7	28.61	0.01	6.68	−0.12	−0.08	7.55
ETH	1962	−55.89	50.94	0.4	7.08	0.11	0.21	10.37
Solana	696	−55.09	49.99	0.41	9.03	0.06	0.52	8.98
XRP	2102	−99.65	93.74	0.16	9.88	−0.06	0.42	28.16
Inflation								
Germany	3241	−0.7	11.60	2.26	2.46	1.7	2.08	6.95
EA20	3241	−0.6	10.60	2.09	2.38	1.4	1.95	6.31
BREIR1	2486	−0.24	6.52	1.16	0.96	0.98	2.77	12.14
BREIR2	2291	−1.9	9.00	1.39	1.45	1.09	2.28	8.29
BREIR3	2386	−2.14	8.89	1.34	1.41	1.04	2.3	8.68
BREIR4	2464	−2.24	8.73	1.31	1.35	1.03	2.24	8.75
BREIR5	2509	−2.5	7.07	1.25	1.22	1.03	2.08	8.67
BREIR6	2729	−2.29	8.64	2.27	1.36	2.25	1.65	7.98
BREIR7	2542	−0.23	5.47	1.1	0.8	0.97	2.78	14.00
BREIR9	2217	−1.96	8.97	1.41	1.49	1.1	2.23	7.95
BREIR9	2217	−1.96	8.97	1.41	1.49	1.1	2.23	7.95

Table 3.1.: Descriptive statistics

log returns	Gold	BTC	Cardano	ETH	Solana	XRP
Gold	1.000					
BTC	0.051**	1.000				
Cardano	0.014	0.719***	1.000			
ETH	0.049**	0.595***	0.773***	1.000		
Solana	0.010	0.525***	0.551***	0.625***	1.000	
XRP	−0.028	0.318***	0.662***	0.393***	0.455***	1.000

Table 3.2.: Correlation of log-return rates
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Overall, the correlation matrix provides initial insights into the relationships between these assets, indicating a prevalent relationship between cryptocurrencies, a strong one in comparison to gold.

Table 3.3 gives a descriptive overview of different control variables that were used in the analysis. The first panel shows different news indices provided by the Economic Policy Uncertainty (EPU) index. The second panel shows a sentiment indicator provided by Eurostat and the percentage changes of the two sentiment indicators included. The last panel gives an overview of financial indicators.
Concerning the news indices, it becomes apparent there are substantial differences among the whole sample period, which is unsurprising as every country has its own economic challenges and difficulties, often, but not exclusively, connected to domestic political decisions. An example is provided by the UK, which has by far the highest values in the sample (max, mean, median, and kurtosis), which indicates high economic uncertainties and which is probably the result or at least the byproduct of BREXIT. Overall, the German and eurozone indicators do not vary significantly, indicating both Germany's substantial role in the EU-wide economy and its capacity to be utilized as an instrument for the EU.
The Economic Sentiment Indicators are roughly equivalent for Austria, Germany and the eurozone, where higher values indicate optimistic expectations of economic development. The percentage changes of the sentiment variables also indicate a similar trend and no substantial outliers.
Term premium, defined as the difference between bonds with longer and shorter maturity, has intuitively rather small values. Its mean and median are roughly the same, indicating rather low volatility. VSTOXX, as an indicator for volatility, measures the overall volatility of the financial markets, where higher values translate into higher volatility. By comparing

its base values with its percentage changes, it is rather constant over time, with a few outliers nonetheless. Another financial market indicator included is the DAX, Deutscher Aktienindex. DAX is a German stock market index representing the performance of the largest and most actively traded companies listed on the Frankfurt Stock Exchange. It serves as a key benchmark for the performance of the German equity market and is considered one of Europe's most important stock indices. Hence, it is included as an instrument for the overall health and direction of the German economy and European financial markets. Its high standard deviation implies it is a somewhat volatile variable. However, by observing it graphically, it becomes obvious it is a rather stable variable, which is also indicated by its logarithmic percentage changes that imply long-term stability.

Variable	N	min	max	Mean	Std. Dev.	Median	Skewness	Kurtosis
News Index								
EA20	3209	111.8	433.28	220.56	67.54	209.74	1.07	4.02
Germany	3209	65.22	844.85	243.23	162.9	192.22	1.91	6.22
Italy	3209	31.7	279.39	126.67	40.93	124.55	0.7	4.01
UK	3209	111.1	1141.80	310.09	145.51	276.29	1.92	9.93
France	3209	132.22	574.63	268.9	79.3	256.62	0.97	4.26
Spain	3209	42.26	282.25	134.38	45.43	129.95	0.73	3.85
Sentiment								
ESI AT	3241	57.8	123.20	100.68	9.52	100.5	-0.48	5.24
ESI DE	3241	67	117.70	104.26	7.24	105	-1.51	8.45
ESI EA	3241	59.7	118.80	100.75	9.11	102.1	-0.95	5.84
%ΔDE News	3208	-50.39	245.35	0.33	8.9	0	10.29	229.47
%ΔEA News	3208	-49.72	118.31	0.13	5.01	0	7.65	162.72
%ΔDE ESI	3240	-26.62	12.21	0	0.7	0	-14.69	711.3
%ΔEA ESI	3240	-36.35	17.26	0	0.86	0	-20.66	1083.43
Financial								
TERM	3226	-0.11	1.27	0.65	0.34	0.66	0.06	1.81
VSTOXX	3216	10.68	85.62	21.81	7.54	20.47	2.02	11.39
%ΔVSTOXX	3190	-35.26	62.56	0.21	7.31	-0.56	1.32	9.55
%ΔTERM1	3210	-5273.03	1002.48	-1.48	96.98	-0.09	-49.76	2725.33
DAX	3230	5080	16334.00	10879.37	2832.08	11214	-.1	2.06
%Δlog DAX	3218	-11.75	10.06	.03	1.27	.08	-.41	9.27

Table 3.3.: Summary statistics of variables

Auto-correlation

Auto-correlation is a fundamental concept in the statistical analysis of time series data. Time series data consist of observations recorded in chronological order, such as daily stock prices. Auto-correlation occurs when current values in a time series are correlated

with past values in the same series. Examining auto-correlations in time series is crucial because it directly contrasts with the assumption of independence of observations in classical statistical procedures. If auto-correlations exist in a time series, it implies that the observations are not independent of each other. This can have significant implications for statistical analysis and may lead to spurious conclusions. Dealing with auto-correlations is essential for creating reliable statistical models and making accurate predictions for time series data.
Figure 3.5 shows different auto-correlation plots for gold and cryptocurrencies in the sample, and 3.6 shows plots of ACF (Auto-correlation function) values for different break-even inflation rates. The plots are constructed as follows. On the y-axis, the ACF values are depicted, which range from -1 to 1, with 0 indicating no auto-correlation, 1 indicating perfect auto-correlation, and -1 indicating perfect negative or inverse auto-correlation. Perfect auto-correlation translates into a strong correlation between lagged values. On the x-axis, the lags of the ACF are included; here, they range from 0 to 40, hence an extended period. The grey shaded areas around the centre represent the 95 % confidence interval, where values within indicate no statistically significant auto-correlation, or in other words, white noise. Values above or below the grey area, however, indicate statistically significant auto-correlation at that lag.

Figure 3.5 indicates very strong auto-correlation between all variables. It is fascinating that the ACF values barely decrease over the whole period (40 lags), except for Solana and XRP. However, these results are not surprising as it is well-known that asset prices are heavily dependent on their lagged values. There are several reasons behind that logic. The main reasons can be summarised as market sentiment and behavioural patterns. Both gold and cryptocurrencies are considered alternative investments or stores of value. Investors react to economic and geopolitical developments or simply market news. Longer trends of increasing prices or simply stabilised price levels can affect market expectations and lead to herding behaviour, which boosts the prevalent trend (both positive and negative) and reinforces the current pricing behaviour. This translates into auto-correlated values in the sense that future prices can be forecasted to some degree based on past values despite partly intense volatility. Of course, no perfect forecasting is possible; nonetheless, the relation between its single values is evident. Another issue that reinforces this trend is the fact that many traders and investors base their decisions on technical analysis of historical price charts and try to analyse whether there are any specific patterns. When a specific technical pattern or support/resistance level is identified, it can lead to buying or selling en masse, reinforcing trends and auto-correlation.

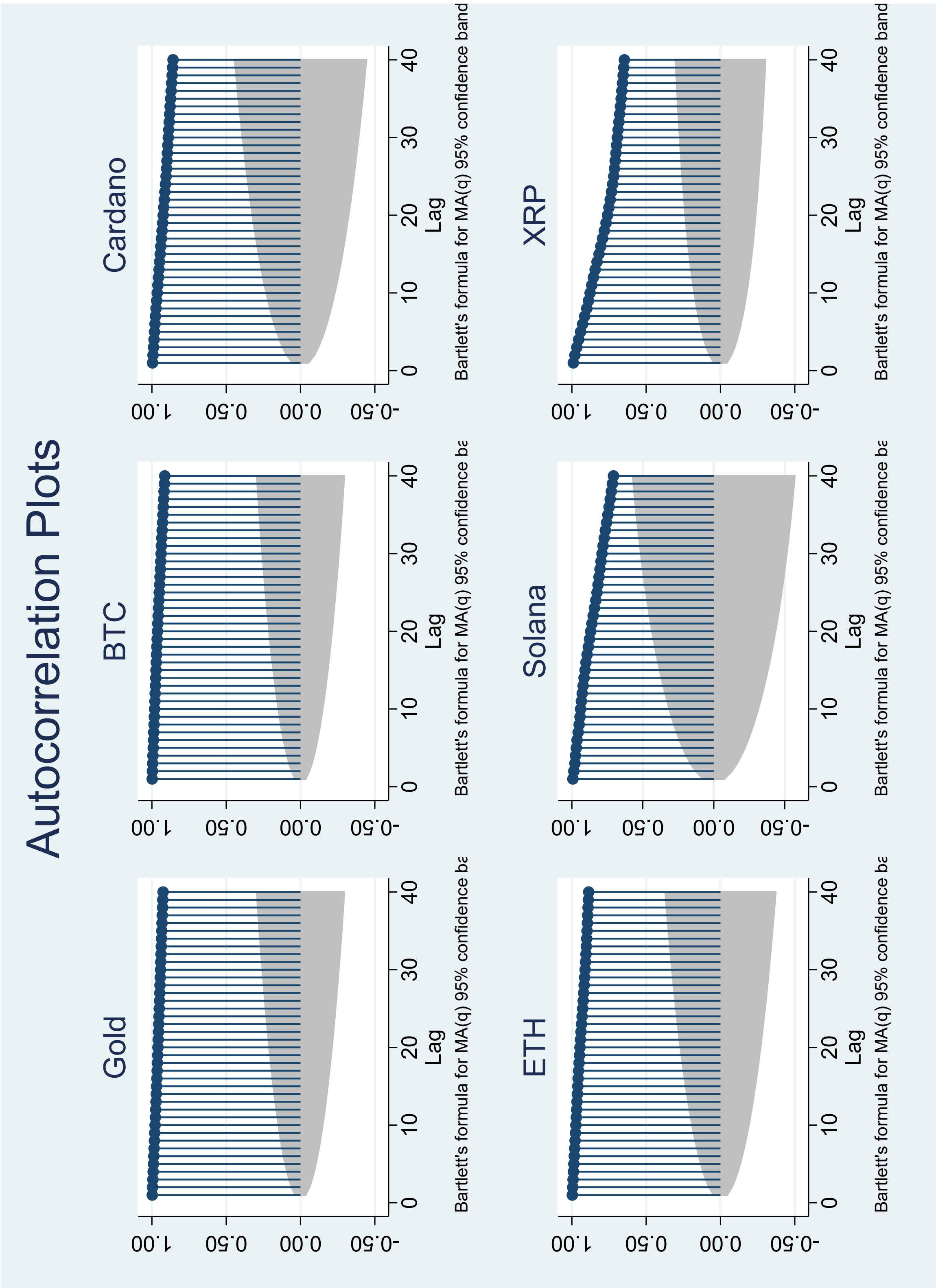

Figure 3.5.: Auto-correlation plots of gold and cryptocurrencies

In summary, auto-correlation in the prices of gold and Bitcoin results from various factors, including investor behaviour, trading patterns, and market dynamics. These factors create a self-reinforcing cycle where past price movements influence future prices, making auto-correlation a standard and expected feature in the analysis of these assets.

Figure 3.6 illustrates the Auto-correlation Function (ACF) plots for nine distinct break-even inflation rates, which are derived from yield spreads between nominal and inflation-protected bonds. These rates serve as vital indicators of market expectations regarding future inflation trends. Notably, these break-even rates exhibit substantial auto-correlation, which is not surprising, as discussed below.
When analyzing break-even inflation rates, similar assumptions apply as when examining actual inflation rates. Expectations play a crucial role. Inflation expectations, a major component of break-even rates, tend to be sticky, meaning that once individuals form expectations about future inflation, they are slow to revise them in response to short-term economic data. These expectations often endure over time.
Anchoring effects, closely related to expectations, also influence break-even rates. Inflation expectations are often anchored to past inflation rates, particularly when extended periods of low inflation volatility occur. Only significant disturbances in inflation levels prompt adjustments to these assumptions. Transition time is another factor; it takes time for new information or shocks to reflect in expectations (noteworthy, it depends on the extent of the specific shock).
Moreover, the calculation of break-even inflation rates relies on bonds, which are subject to market dynamics and trading behaviour. As mentioned above, various factors can influence auto-correlation in these rates.
Additionally, break-even rates tend to reflect smooth transitions in inflation rates rather than sudden spikes. This characteristic further contributes to auto-correlation within break-even inflation rates. In summary, factors such as inertia, anchoring effects, delayed adjustments in expectations, market dynamics, and the anticipation of smooth transitions collectively contribute to the observed auto-correlation in break-even inflation rates.

Transformation of time-series variables

As Figure 3.5 and 3.6 illustrate the prevalence of serious auto-correlation within the variables, which can pose challenges in statistical analysis, further measures are necessary. Auto-correlation, or the tendency of data points to be correlated with previous data points, can lead to biased parameter estimates and unreliable statistical inferences. Detecting

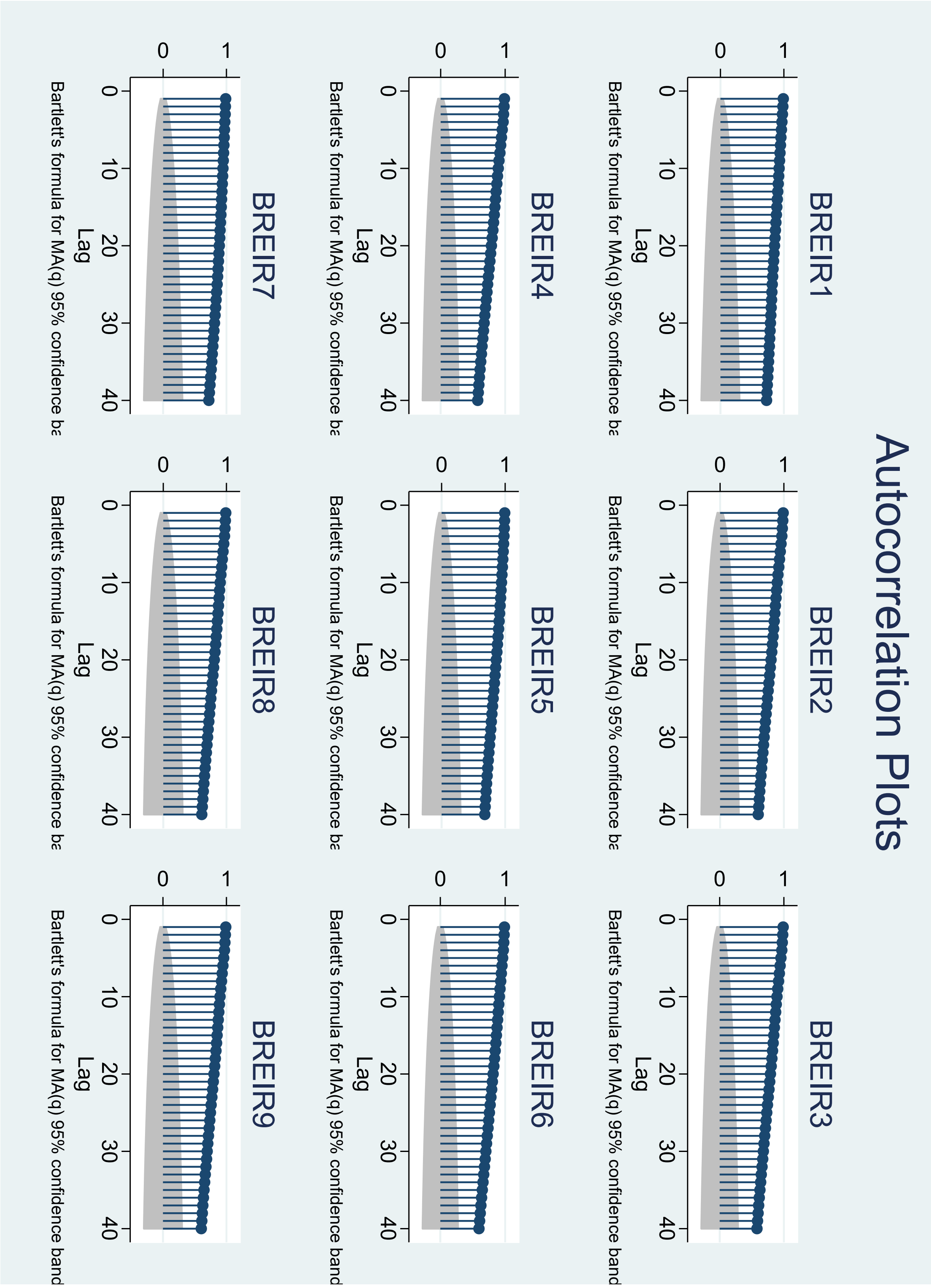

Figure 3.6.: Auto-correlation plots of Break-even inflation rates

auto-correlation is crucial for ensuring the accuracy of economic and financial models. One way to identify auto-correlation is using statistical tests like the Augmented Dickey-Fuller (ADF) test. The ADF test examines whether a time series possesses a unit root, which implies that it is non-stationary and exhibits auto-correlation. If the test indicates the presence of a unit root, measures like taking the first difference or further transformations of the time series may be necessary to make it stationary and remove auto-correlation. For break-even inflation rates, taking the difference can be achieved through calculating the percentage change from the previous day. This transformation makes the data more stationary and reduces the impact of auto-correlation. Another effective approach to address auto-correlation is applying transformations like the logarithmic percentage change (Wooldridge, 2013).

Variables	ADF-Statistic	p-value	1% level	5% level	10% level
Gold	−0.594	0.872	−3.430	−2.860	−2.570
Gold USD	−1.270	0.643	−3.430	−2.860	−2.570
BTC	−1.350	0.606	−3.430	−2.860	−2.570
Cardano	−1.710	0.426	−3.430	−2.860	−2.570
ETH	−1.501	0.533	−3.430	−2.860	−2.570
Solana	−1.266	0.645	−3.430	−2.860	−2.570
XRP	−3.221**	0.019	−3.430	−2.860	−2.570
log Gold	−56.598***	0.000	−3.430	−2.860	−2.570
log Gold USD	−56.426***	0.000	−3.430	−2.860	−2.570
log BTC	−60.124***	0.000	−3.430	−2.860	−2.570
log Cardano	−38.472***	0.000	−3.430	−2.860	−2.570
log ETH	−44.696***	0.000	−3.430	−2.860	−2.570
log Solana	−25.882***	0.000	−3.430	−2.860	−2.570
log XRP	−57.089***	0.000	−3.430	−2.860	−2.570

Table 3.4.: Augmented-Dickey Fuller Test, returns
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 3.4 shows the results of the Augmented Dickey-Fuller test on price levels of gold and cryptocurrencies. Unsurprisingly, the null hypothesis of a prevalent unit-root cannot be rejected for absolute price levels (except for XRP). This result verifies the assumption above, that the price levels are not stationary. However, the logarithmic transformation of calculating the return levels solves the problem. The lower panel shows the ADF-statistics after the return rates were calculated. Now, the null hypothesis of a unit-root can be safely rejected for all variables (p<0.01) which means the variables are stationary and hence suitable for time-series analysis.

Table 3.5 depicts the same test statistics on expected inflation rates. Again, none of the null hypotheses of a unit-root can be rejected for absolute levels of expected inflation rates. However, after calculating the percentage change of inflation rates, all of them are stationary (p<0.01), which indicates that in both cases, the transformations of the variables solved the problem of prevailing auto-correlation issues. The rendered data is now more suitable for analytical analysis that assumes independence between observations.

Variables	ADF-Statistic	p-value	1% level	5% level	10% level
BREIR1	1.374	0.997	−3.430	−2.860	−2.570
BREIR2	−1.331	0.615	−3.430	−2.860	−2.570
BREIR3	−1.387	0.588	−3.430	−2.860	−2.570
BREIR4	−1.455	0.556	−3.430	−2.860	−2.570
BREIR5	−0.783	0.824	−3.430	−2.860	−2.570
BREIR6	−2.125	0.235	−3.430	−2.860	−2.570
BREIR7	1.289	0.997	−3.430	−2.860	−2.570
BREIR8	−1.341	0.610	−3.430	−2.860	−2.570
BREIR9	−1.335	0.613	−3.430	−2.860	−2.570
%ΔBREIR1	−45.169***	0.000	−3.430	−2.860	−2.570
%ΔBREIR2	−39.012***	0.000	−3.430	−2.860	−2.570
%ΔBREIR3	−49.049***	0.000	−3.430	−2.860	−2.570
%ΔBREIR4	−50.542***	0.000	−3.430	−2.860	−2.570
%ΔBREIR5	−52.330***	0.000	−3.430	−2.860	−2.570
%ΔBREIR6	−47.985***	0.000	−3.430	−2.860	−2.570
%ΔBREIR7	−48.749***	0.000	−3.430	−2.860	−2.570
%ΔBREIR8	−38.072***	0.000	−3.430	−2.860	−2.570
%ΔBREIR9	−37.066***	0.000	−3.430	−2.860	−2.570

Table 3.5.: Augmented-Dickey Fuller Test BREIR
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Additional tests were performed for the remaining variables as well, yielding similar results and transformations, where necessary, have been conducted accordingly. In conclusion, the transformed variables are stationary and appropriate for the endeavour of time-series analysis.

3.3. Results

This section presents the results, split into three parts; first, the whole sample period is examined, and subsequently, the whole period is separated into a pre- and post-inflation shock period, so to speak, and concludes with a discussion of the findings.

3.3.1. Whole sample period

First, results for the whole sample period (mid-2012 to mid-2023) are presented. In Table 3.6, the correlation between prices of gold and cryptocurrencies (left row) and different measurements of inflation (top column) are shown for illustration purposes. Significance levels are depicted by the number of asterisks next to the coefficient.
Both inflation levels of Germany and the eurozone are included, as well as one measurement of expected inflation. Based on the latter, unexpected inflation rates for Germany and the eurozone are calculated, respectively. The results are all highly statistically significant (p<0.01). Gold has very high correlation values among all inflation indicators, closely followed only by ETH. Especially with regard to unexpected inflation, gold and ETH both have a strong correlation, with the latter even realising a stronger correlation than gold. BTC is somewhere in-between but still shows a moderate to strong correlation with inflation levels. Cardano, Solana and XRP all show little to moderate correlation. In comparison to gold, ETH and BTC are only moderately but still stronger than the remaining cryptocurrencies correlated with inflation.

	Inflation Germany	Inflation EA20	exp. Inflation	unexp. Infl. GER	unexp. Infl EA20
Gold	0.648***	0.645***	0.307***	0.644***	0.672***
BTC	0.507***	0.465***	0.276***	0.504***	0.491***
Cardano	0.312***	0.286***	0.249***	0.284***	0.244***
ETH	0.635***	0.620***	0.461***	0.548***	0.527***
Solana	0.171***	0.150***	0.190***	0.139***	0.103***
XRP	0.331***	0.326***	0.215***	0.315***	0.309***

Table 3.6.: Correlation: prices and inflation
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 3.7 is structured the same as above, with the only difference being that instead of nominal price levels, it now contains log returns, and the inflation rates have been replaced by the percentage change in inflation rates, in order to control for auto-correlation.

First of all, the table now depicts fewer statistically significant results. Gold returns show a low negative correlation with percentage change in inflation within the eurozone.

	%ΔInflation Germany	%ΔInflation EA20	%Δexp. Inflation	%Δunexp. Infl. GER	%Δunexp. Infl EA20
log Gold	0.001	−0.036**	0.010	0.001	−0.012
log BTC	−0.011	−0.018	0.022*	−0.009	0.032*
log Cardano	−0.032	−0.031	0.041*	−0.020	−0.054*
log ETH	−0.040*	−0.071***	0.043*	−0.015	0.008
log Solana	−0.129***	−0.201***	0.102**	0.031	0.008
log XRP	0.052**	0.000	0.019	−0.005	0.007

Table 3.7.: Correlation: log returns and percentage change in inflation
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

In contrast, BTC shows a positive correlation, to the same extent as gold, with unexpected percentage change with the eurozone. Returns of all BTH, Cardano, ETH and Solana show a moderate positive correlation with expected inflation change. However, except from Solana (p<0.05) only on a low significance level (p<0.1). The results are ambivalent, especially when considering that ETH and Solana have a statistically significant negative relation with actual percentage change but, at the same time, a positive relationship with the percentage change in expected inflation. The results indicate varying degrees of correlation between these assets and inflation rate changes. Gold, Cardano, Ethereum, and Solana generally show negative correlations, while XRP exhibits a positive correlation with inflation changes in Germany. Bitcoin's correlation is negative but not statistically significant, suggesting it may not serve as a strong inflation hedge. These findings highlight the complexity of asset-inflation relationships and the importance of diversification when considering inflation protection strategies.

Table 3.8 represents the results of the baseline regression models, where the coefficients can be illustrated as follows: $(e^{\hat{\beta}} - 1) \times 100$ translates to the change in R_t in base points (bps).
The first row depicts the logarithmic return of gold, BTC, Cardano, ETH, Solana and XRP, respectively. The left column shows the explanatory variables included in the model, namely the percentage change of expected inflation, a lag of the return, and a series of control variables that correct for the overall condition of the financial market.
The results are to be interpreted as follows: The individual coefficients are in the same line as the variable names, and significance levels are depicted by an asterisk next to them, where the number of asterisks correlates as *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, respectively. The standard errors are in parentheses below the coefficients. At the bottom, the adjusted R^2, the F-Statistics and the absolute number of observations are shown.

This analysis's main explanatory variable of interest is expected inflation, or percentage change in expected inflation, to overcome auto-correlation. The coefficient of $\%\Delta$ of BREIR is negative for all asset returns; however, they are both negligibly small (close to 0) and, more importantly, not statistically significant for either of the asset classes. Hence, the assumption of both gold and cryptocurrencies serving as hedges against expected inflation would be contradicted in this setting.
Notably, even the lag of their returns is not statistically significantly different from zero for most assets. This is especially interesting; as shown above, their prices are severely auto-correlated. The lag returns of both Cardano and XRP are negative and statistically significant ($p<0.01$). Their negative value could indicate strong volatility, as future returns are in the opposite direction as their past returns.
To overcome auto-correlation and standardise comparison of the coefficients, implied volatility, as measured by VSTOXX, is also included in the form of a percentage change to its prior period. It is striking that the returns of gold are the only ones that react positively to higher volatility. This indicates that economic uncertainty, as indicated by implied volatility, correlates to positive returns of gold; even though the coefficient is minimal, it is, nonetheless, further evidence for gold serving as a safe-haven currency ($p<0.01$) while it would predict the contrary for cryptocurrencies.

Concerning Term premium, all asset returns seem to be independent of ECB bond yields. That interpretation also aligns with the insignificant relationship between asset returns and expected inflation rates.
The same result applies to economic uncertainty, as instrumented by Economic Policy Uncertainty. This indicates no significant relationship between asset returns and the change of economic uncertainty measured by articles in major newspapers. Accordingly, changes in the Economic Sentiment Indicator also bear no significant results (except Solana, but only at the 10% significance level).
Admittedly, the last parameter ($\log\%\Delta$ DAX) was only included because the break-even inflation rates were based on German bonds. Notably, the DAX index yields the most significant results, significant values for the returns on BTC, Cardano, ETH and Solana ($p<0.01$), which indicates that a positive development of German companies, as indicated by an increase in DAX values, correlates to a positive price development of cryptocurrencies. Solana and Cardano register the highest correlated increase; hence, cryptocurrencies that have a relatively low value and small volume in comparison to BTC and ETH. Gold shows no correlation with the DAX index, which underscores two interpretations, namely its role as a potential safe-haven and as a diversifier in combination

	r gold	r BTC	r Cardano	r ETH	r Solana	r XRP
Constant	0.007	0.316	−0.054	0.337	0.265	0.277
	(0.016)	(0.122)	(0.185)	(0.003)	(0.348)	(0.218)
%ΔBREIR	0.000	−0.001	−0.001	0.000	−0.004	0.000
	(0.000)	(0.003)	(0.003)	(0.023)	(0.004)	(0.005)
L.*log* return	0.031	−0.026	−0.068***	0.003	0.008	−0.212***
	(0.019)	(0.019)	(0.028)	(0.031)	(0.038)	(0.022)
%ΔVSTOXX	0.010***	0.020	−0.003	0.029	0.024	−0.051
	(0.003)	(0.024)	(0.035)	(0.001)	(0.068)	(0.042)
%ΔTERM	0.000	0.000	−0.001	0.000	0.000	0.000
	(0.000)	(0.001)	(0.001)	(0.017)	(0.002)	(0.002)
%ΔNews Index	0.001	−0.013	0.025	0.007	0.029	−0.004
	(0.002)	(0.014)	(0.025)	(0.195)	(0.053)	(0.023)
%ΔESI	0.038	−0.090	0.143	0.124	0.907*	0.192
	(0.023)	(0.172)	(0.185)	(0.187)	(0.546)	(0.272)
%Δlog DAX	0.022	0.533***	1.052***	0.842***	1.638***	0.331
	(0.020)	(0.146)	(0.210)	(0.19)	(0.429)	(0.253)
Adj. R^2	0.004	0.006	0.046	0.015	0.043	0.046
F-Statistic	2.729	3.428	9.714	5.011	5.184	14.886
No. Obs.	2681	2681	1256	1876	651	2013

Table 3.8.: Multivariate Regression for Gold, BTC, Cardano, ETH, Solana, and XRP
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

with cryptocurrencies.
Overall, based on the F-Statistics, it can be concluded that the null hypothesis (all parameters equal to zero) can be rejected for each model. Nonetheless, the explanatory power of the models is negligible, as their adjusted R^2-values are relatively small, which prompts two conclusions: 1) Cryptocurrencies and gold are rather independent of economic developments as implied by financial market data (except for DAX) or economic sentiment indicators. 2) According to this analysis, neither gold nor cryptocurrencies qualify as hedges against inflation; nonetheless, gold's potential as a safe-haven is reconfirmed.

3.3.2. Comparison between periods pre- and post-inflation shock

As shown above, the dataset has significant differences in inflation rate levels. Consequently, it is reasonable to compare the periods before and after the shock in inflation to gain further insights into the inflation-hedging properties of gold and cryptocurrencies, especially in exceptional times. The cut-off point was set at the end of December 2020, as inflation rates began to surge as early as January 2021 (see, for example, Figure 3.1). This chosen date offers several advantages. Firstly, it sheds light on two entirely distinct periods, with the former period being, on average, close to the ECB's target inflation level of 2% and a key interest rate close to or even below zero, and the latter achieving inflation rates entirely unfamiliar in the recent past within the eurozone and also achieving new peaks of key interest rates. Secondly, through this cut-off point, both periods still provide substantial data, allowing for meaningful comparisons between them. Note that Solana is not included in the following comparison. As it is the most recently established cryptocurrency included in the analysis, there is insufficient data before the cut-off point for a comparison. The regression results of the comparison between pre- and post-inflation shock are depicted in Tables 3.9 and 3.10. The tables are constructed precisely as above, with the log returns of gold and cryptocurrencies in the top row and the explanatory variables in the left column.

Pre-2021-inflation shock

This period now spans from 2012 to the end of 2020; thus, in descriptive terms, the most obvious difference in comparison to the whole period is the constant low inflation rate; therefore, expected inflation is also rather low (see Figure 3.1). However, this is also connected to relative stability in financial markets and overall economic variables. Hence, all control variables display less volatility and lower extreme values. The regression results of the pre-inflation shock period are shown below in Table 3.9.

The most striking difference compared to the whole sample period above is that now, suddenly, the major variable of interest, the percentage change in the break-even inflation rate, is statistically significant for three out of five variables, namely for gold, Cardano and Ethereum. Overall, now, relatively many variables are statistically significantly different from zero. This can be an indication that the surge in inflation heavily distorted the usual trends.

With regard to inflation-hedging properties, gold shows inferior capacity than Cardano and Ethereum. Gold has an inverse relationship with BREIR, which means that with increases in expected inflation, the returns of gold decrease. Therefore, gold seems to not qualify, in the sample period, as a reasonable hedge against inflation. Even though the coefficient is rather small, it is highly significant. Noteworthy, the interpretation of this coefficient is somewhat ambiguous and requires some caution. Recall during the study period, the eurozone faced partly very low inflation rates, some of which even fluctuated into negative territory. As inflation exhibited a downward trend, this translated into economic expectations as well, resulting in a partly negative trend in expected inflation. This means that the percentage change from the previous day is often negative. For illustration, the mean of the variable "percentage change BREIR" is slightly negative during this sample period. In other words, gold returns are negatively correlated with a predominantly negative variable. This implies that, on average, gold returns have increased, which could be translated as a partial inflation-hedge during this period. A 1% decrease in expected inflation would translate to a decrease in gold returns by approximately 2.9 bps. Accordingly, the results for the remainder of the returns has to be interpreted with caution as well. While BTC and XRP are not statistically significant, ETH and Cardano show positive inflation-hedging properties. Notably, the number of observations is much smaller in the case of Cardano as it is a relatively new cryptocurrency; nonetheless, it exhibits the best properties in protecting an investor against inflation (at least in theory as the percentage change is mostly negative).

	r gold	r BTC	r Cardano	r ETH	r XRP
Constant	0.000	0.269	−0.192	0.410	0.350
	(0.018)	(0.156)	(0.251)	(0.208)	(0.276)
%ΔBREIR	−0.029***	0.008	0.111***	0.017**	0.009
	(0.006)	(0.006)	(0.054)	(0.007)	(0.010)
L.*log* return	0.049**	−0.072***	−0.063*	0.016	−0.240***
	(0.021)	(0.023)	(0.037)	(0.027)	(0.026)
%ΔVSTOXX	0.012***	0.055*	0.021	0.091**	−0.024
	(0.004)	(0.031)	(0.047)	(0.039)	(0.053)
%ΔTERM	−0.026***	−0.026	−0.111	−0.109*	0.143*
	(0.007)	(0.051)	(0.071)	(0.066)	(0.085)
%ΔNews Index	0.001	−0.009	0.026	0.013	−0.006
	(0.002)	(0.016)	(0.032)	(0.020)	(0.027)
%ΔESI	0.037	−0.048	0.001	0.042	0.124
	(0.026)	(0.204)	(0.205)	(0.231)	(0.322)
%Δlog DAX	0.068***	0.595***	1.057***	0.991***	0.194
	(0.022)	(0.182)	(0.251)	(0.233)	(0.310)
Adj. R^2	0.031	0.009	0.051	0.015	0.058
F-Statistic	10.611	3.365	6.297	3.835	13.793
No. Obs.	2114	1851	689	1876	1445

Table 3.9.: Multivariate Regression pre inflation-shock
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

The lagged return is statistically significant for every variable except for Ethereum. While gold is the only one that reacts positively to its former return rate, all cryptocurrencies have negative (significant) coefficients, which implicates the comparatively higher volatility of cryptocurrencies, contrary to gold.

Implied volatility is significant for three, and Term premium for two variables. Noteworthy, the direction of the relation is diametrically between the two control variables, which, intuitively, makes sense. If implied volatility is high, it indicates that there prevails uncertainty towards traditional financial assets; hence, gold and cryptocurrencies might be a reasonable alternative. Consequently, if the Term premium increases, that means either long-term bonds' yield increases or short-term bonds' yield decreases, cet. par. In either case, long-term bonds gain popularity, attracting investors, which could imply a decrease in returns for gold and cryptocurrencies.
Analogous to the whole period above, neither the News index nor the Economic Sentiment Indicator showed significant results. Again, the most influential variable is the DAX index, which shows high coefficients, especially for Ethereum and Cardano, not significant only for XRP, which was also the only cryptocurrency in the whole sample period with no statistically significant relationship with the DAX index. This result clearly shows that the German stock market moves strongly in the same direction as gold and cryptocurrency returns. Noteworthy, however, are the relatively large standard errors, which imply volatility to some extent.
The adjusted R^2 is still rather small, indicating, most of all, that expected inflation has not been a reliable explanatory variable for return rates of neither gold nor cryptocurrencies. According to the F-Statistics, the models are significantly different from zero.

Post-2021-inflation shock

Table 3.10 presents the regression results covering the period from early 2021 to mid-2023, encompassing the period characterized by exceptionally high inflation rates. Consequently, the dataset contains a significantly lower number of observations compared to the preceding panels. It is important to exercise caution when interpreting, and especially comparing, these results due to the relatively shorter time period under consideration.
Firstly, Cardano, which displayed the strongest correlation with expected inflation, shows no statistically significant inflation-hedging properties after 2021. However, in the comparison before and after risen inflation, Cardano has the fewest observations. Gold, BTC, ETH and XRP all show statistically significant inflation-hedging properties. In times of financial distress, gold displays its role as a potential safe-haven. Even though gold's coefficient is the smallest, none of them seem to offer strong protection against inflation. The coefficients of lagged returns imply higher volatility for the second period that is analysed; all coefficients are negative and not statistically significant, which could be

interpreted as higher volatility. Implied volatility and Term premium are only significant for one cryptocurrency, respectively (p<0.1). Hence, no comprehensive interpretation of the relationship between the financial market and return rates is possible for the period starting in 2021. News index and Economic Sentiment again show no statistical significance; hence, they surprisingly demonstrate no explanatory power in any of the models.

	r gold	r BTC	r Cardano	r ETH	r XRP
Constant	−0.007	−0.084	0.226	0.130	−0.169
	(0.040)	(0.248)	(0.389)	(0.294)	(0.445)
%ΔBREIR	0.043***	0.120***	0.072	0.154**	0.204**
	(0.010)	(0.045)	(0.071)	(0.073)	(0.081)
L.*log* return	−0.053	−0.017	−0.073	−0.066	−0.026
	(0.048)	(0.049)	(0.05)	(0.045)	(0.052)
%ΔVSTOXX	−0.011	−0.056	−0.026	−0.101*	−0.016
	(0.007)	(0.045)	(0.071)	(0.055)	(0.081)
%ΔTERM	−0.004	−0.027	−0.110*	−0.062	−0.023
	(0.006)	(0.040)	(0.063)	(0.045)	(0.073)
%ΔNews Index	0.005	0.002	0.035	−0.011	0.023
	(0.006)	(0.034)	(0.053)	(0.042)	(0.060)
%ΔESI	0.069	−0.049	0.821	0.534*	0.811
	(0.062)	(0.39)	(0.609)	(0.453)	(0.697)
%Δlog DAX	−0.172***	0.861***	1.227**	0.892**	1.326**
	(0.052)	(0.330)	(0.517)	(0.385)	(0.592)
Adj. R^2	0.066	0.093	0.054	0.097	0.097
F-Statistic	5.264	6.496	4.099	7.437	3.556
No. Obs.	419	375	375	419	375

Table 3.10.: Multivariate Regression post inflation-shock
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

The DAX index is again highly significant; gold has had a negative relationship with the DAX, contrary to all of the cryptocurrencies. This means a negative relationship exists between the DAX index and gold returns (at least in times of uncertainty). In other words, when the DAX index rises, Gold returns tend to decrease. The coefficients for BTC, Cardano, ETH and XRP are positive and statistically significant. This suggests a positive relationship between the DAX index and the returns of these cryptocurrencies. When the DAX index rises, the returns of these cryptocurrencies tend to increase. These results are in line with the safe-haven assumption of gold, i.e. an asset that can rise in times of market turbulence. At the same time, cryptocurrencies tend to have a positive relationship with stock markets, as represented by the DAX index. Again, the DAX coefficients exhibit high standard errors for the cryptocurrencies. Therefore, the results must be interpreted with caution. Nonetheless, the results reveal that both gold, as the classical asset form, and cryptocurrencies, as a relatively new form, show moderate inflation-hedging properties. While the R^2 is still rather low, the models post-inflation-shock seem to have the greatest explanatory power, again, all significantly different from zero.

3.4. Discussion

In this analysis, the inflation-hedging properties of both traditional assets like gold and emerging assets like cryptocurrencies, specifically Bitcoin (BTC), Cardano (ADA), Ethereum (ETH), Solana, and XRP, were examined. After a theoretical description of the dataset, the methodological transformation was outlined to prevent spurious regression results due to auto-correlation. The analysis proceeded with three different periods to shed more light on periods marked by economic uncertainty. First, the entire dataset was analysed, spanning the period from mid-2012 to mid-2023, and then the periods before and after the sudden increase in inflation rates were compared; hence, the period before the 2021 inflation shock and the period after the 2021 inflation shock. Due to high volatility in inflation, as well as other variables, within the entire sample period, this separation allows for meaningful comparison and conclusions from two very distinct periods, with the former exhibiting inflation rates that are, on average, close to the ECB's target and the latter exhibiting unusually high inflation rates.

Entire Dataset (2012-2023)

In the entire dataset, neither gold nor cryptocurrencies demonstrated substantial and statistically significant inflation-hedging properties. The coefficients for the percentage change in expected inflation rates were generally small and not statistically significant for most assets. This suggests that these assets did not consistently serve as reliable hedges against expected inflation during this entire period. Notably, even the lagged returns of these assets were mostly not statistically significant, underscoring the assumption that returns are not auto-correlated. Only Cardano and XRP displayed statistically significant lagged returns, which may imply high volatility throughout the entire sample period, as evidenced by their negative coefficients. Gold was the only currency that displayed a positive relationship with implied volatility (VSTOXX), indicating its potential as a safe-haven asset during times of economic uncertainty and highlighting the divergence of crypto markets from traditional financial markets. Noteworthy, the DAX index appeared to strongly influence crypto-returns, serving as an explanatory variable for crypto-returns, but not gold. This further emphasizes gold's potential as a safe-haven, as it is detached from regular financial assets. In summary, none of the assets demonstrated consistent inflation-hedging properties throughout the entire period, and the model exhibited limited explanatory power, indicating that other factors are decisive for predicting returns.

Pre-2021 Inflation Shock

Expected inflation is not entirely insignificant anymore. From 2012 to 2020, gold exhibited a negative relationship with expected inflation, while Cardano and Ethereum displayed positive and statistically significant inflation-hedging properties. Noteworthy, percentage changes in expected inflation were overwhelmingly negative, indicating partial inflation-hedging properties of gold, which would result in gold being the only asset serving as a (weak) inflation-hedge in this period. The lagged returns once again underscore the relatively high volatility of cryptocurrencies compared to gold. The results of economic and financial indicators deviate from those of the entire sample period. Gold, BTC, and ETH exhibit a positive and significant relationship with VSTOXX, indicating that higher volatility is associated with rising returns. The DAX index shows a positive correlation with gold, BTC, Cardano, and ETH, with the smallest effect observed in the case of gold.

Post-2021 Inflation Shock

After the 2021 inflation shock, the dataset covered a period of exceptionally high inflation rates. Gold maintains its perception as a (weak) hedge against expected inflation, displaying a significant positive relationship. However, this relationship is relatively weak compared to the cryptocoins Bitcoin, Ethereum, and XRP, which showed statistically significant inflation-hedging properties, indicating that they might provide some protection against inflation during this turbulent period. Lagged returns are insignificant for all assets in this period, as are most of the economic and financial indicators, indicating uncertainty among these markets. In this period, the DAX index is highly significant for all assets, positively correlated with cryptocurrencies and negatively with gold, hence again underscoring the potential of gold as a safe-haven. At the same time, the crypto-market is somewhat intertwined with regular stock markets. A significant limitation, however, is that the period of unusually high inflation rates is not over yet; hence, a re-evaluation in another year could yield exciting insights.

3.5. Final remarks

The results indicate that the relationship between asset returns, inflation and other economic variables can depend highly on the economic environment as the comparison between the two periods differs substantially. In times of relative economic stability, as indicated by low and decreasing inflation rates and steady interest rates, traditional assets like gold proved to be the best hedge against expected inflation - even though only through its inverse relationship with negative percentage changes in expected inflation. However, during periods of uncertainty or high inflation, gold, especially Bitcoin and Ethereum, demonstrated the potential to provide moderate protection against inflation. Across all periods, the German stock market index, DAX, consistently showed a significant relationship with the returns of these assets. Generally, when the DAX rises, the returns of cryptocurrencies tend to increase, while gold displays the opposite trend. This suggests that cryptocurrencies are positively correlated with stock market movements. At the same time, gold emphasizes its role as a traditional safe-haven that does not co-move strongly with traditional stocks. Noteworthy, these insights shed light on how crypto-assets react much stronger to traditional financial assets than to (expected) inflation. Therefore, it is crucial to note that, according to the findings in this research, these assets do not qualify as reliable hedges against inflation. Additionally, cryptocurrencies exhibited higher volatility and less consistent relationships compared to gold. In conclusion, the role of gold and cryptocurrencies is highly distinctive, which rejects the notion of Bitcoin as the new digital gold. Nonetheless, by no means could the inflation-hedging properties of gold be described as perfect; hence, diversification and a clear investment strategy are vital to protect investors against purchasing power loss from inflation, as none of the examined assets show adequate protection.
Overall, the findings are in line with recent research in this field while still distinctive. While Smales finds inflation-hedging properties of both gold and cryptocurrencies over an extended period in the US, in Europe, cryptocoins only show robust hedging potential in the latter, inflation-ridden period. Choi and Shin examine a period comparable to the latter period here, and they come to the conclusion that Bitcoin was a reliable hedge during COVID-19 (Choi & Shin, 2022; L. A. Smales, 2022). In conclusion, the conducted research finds partial inflation-hedging properties of both gold and cryptocurrencies that vary over time. Due to contradicting behaviour as a safe-haven asset of the latter, the notion of Bitcoin as digital gold should not be accepted, if not rejected.

4. Conclusion

The main objective of this thesis was to compare the inflation-hedging properties of gold and cryptocurrencies to mitigate purchasing power loss, which is especially relevant in times of high inflation rates. Chapter 2 provided a comprehensive overview of the theoretic foundation, outlining the diverse range of arguments regarding the causes and effects of inflation from the point of view of various schools of thought. This extensive discussion exemplifies the fact that inflation is a highly debated phenomenon without a clear consensus, especially regarding methods to protect against real income erosion. Additionally, a brief summary was provided of gold's historical significance as a trusted medium of exchange, its gradual replacement by fiat money due to economic constraints and its separation from legal tender since the abolishment of the gold standard. These developments paved the way for digital currencies, including, last but not least, Bitcoin, which continue to shape today's evolving financial landscape.

The notion of *Bitcoin as the new digital gold* has frequently appeared in various newspapers and journals. Either as an attempt to find an explanation for a relatively new financial phenomenon or simply advertising its role as a new medium of exchange without a proper understanding of its underlying structures. Consequently, this thesis examined the prevalent comparison between gold and Bitcoin, particularly while including several other cryptocurrencies. In order to examine whether these headlines held any inherent truth, the issue was addressed through time-series regression analysis. The relationship between returns of Gold, Bitcoin (BTC), Cardano, Ethereum (ETH), Solana, and XRP (Ripples) on the one hand, and expected inflation rates, lagged returns, and several control variables on the other hand, was analysed. The findings unveiled the intricate dynamics within these asset classes, providing insights into their roles as potential hedges against inflation.

The results of the analysis are threefold, as the whole sample period was separated into a pre- and post-inflation shock period. The surging inflation rate levels starting in 2021 suggest such a distinction for a more reasonable analysis and to better understand how these assets react to economic uncertainty. The analysis of the whole sample period revealed that the percentage change in expected inflation, a pivotal variable of interest, exhibited a negligible and statistically insignificant relationship with the returns of these assets. This suggests that, within the scope of this analysis, neither gold nor cryptocurrencies can be reliably considered long-term hedges against expected inflation if the period of interest is characterised by significant distortions.

As the empirical part distinguishes between a pre- and a post-inflation shock period, it allows for more detailed conclusions. Strikingly, gold shows a negative relationship with expected inflation prior to 2021. Hence, in this period, gold had an inverse function as an inflation-hedge, while Cardano and Ethereum showed moderate properties as partial inflation-hedges. Nonetheless, these results demand caution while interpreting them; the percentage change in expected inflation was, on average, negative in this period, suggesting that gold served partially as an inflation-hedge in this period. Until 2020, some signs suggest both gold and cryptocurrencies may have functioned as alternative investment options to traditional financial assets. This potential relationship could be associated with the prevailing low-interest rates during this period and is partly confirmed by the positive association with implied volatility and negative association with Term premium.

After 2020, gold underlined, again, its reputation as a modest hedge against inflation and as a safe-haven asset. However, all cryptocurrencies except for Cardano demonstrated more robust inflation-hedging characteristics during this period, indicating they might partly hedge inflation in times of economic uncertainty. The connection with financial indicators is not as pronounced as before, suggesting increased uncertainty in financial markets on the one hand, but it might also be indicative of the initial impact of rising interest rates on the other hand.

Moreover, despite the presence of auto-correlation in asset prices, lagged returns were generally not statistically significant for the entire sample period. However, when examining the two sub-sample periods, lagged returns indicated higher volatility within the crypto-market compared to gold.

Implied volatility, measured by VSTOXX, and Term premium, measured by the difference between the interest rates on long- and short-term ECB bonds, revealed that gold responded positively to higher volatility levels, aligning with the perception of gold as a safe-haven asset during economic and financial uncertainty, which is in line with several other research in this regard.

Additionally, the analysis highlighted the potential influence of the DAX index, representing German equity markets, on the returns of cryptocurrencies. This finding underscores the importance of considering global economic developments in understanding the dynamics of these digital assets. Moreover, it suggests that cryptocurrencies are closely related to traditional financial assets, while gold qualifies more as a safe-haven, that is not as strongly (and partly negatively) correlated with stock markets, which again strengthens the view of rejecting the notion of Bitcoin as digital gold.

While this analysis already offers valuable insights, it also points to several potential extensions for further research. Subsequent investigations could delve into the long-term relationship between cryptocurrencies and inflation rates, taking into account the potential impact of interest rates, currency fluctuations, and more specific macroeconomic indicators. Additionally, a reiteration of this analysis conducted here, when inflation may have returned to its pre-2021 levels, could provide more comprehensive insights into the period of exceptionally high inflation rates. Moreover, the effects of regulatory developments on these asset classes deserve deeper examination, as regulatory changes can significantly impact the whole crypto-market, or potentially single cryptocurrencies. Finally, considering the interconnectedness of financial markets, a holistic approach incorporating multiple variables is essential in gaining a more comprehensive understanding of these complex assets.

In conclusion, this analysis contributes to understanding the factors influencing the returns of gold and cryptocurrencies. It emphasises the need for further research to uncover the numerous determinants shaping their market dynamics. According to this model, inflation alone is insufficient in explaining returns of assets like gold and cryptocurrencies, and consequently, they may not serve as reliable hedges against inflation. They may serve as moderate inflation hedges. Regarding the frequent comparison between gold and Bitcoin, while significant common features are prevalent, they also exhibit distinct market behaviours. Therefore, the assumption that Bitcoin is the New Digital Gold may not hold, as suggested by the results of this research.

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A. Appendix

BREIR - ISIN:

Specifically, the following bonds were used for calculating the break-even inflation rates, as denoted by the ISIN:

ISIN	Type	Maturity
DE0001030583	Inflation-indexed bond	Anl.v.21(33)
DE0001030575	Inflation-indexed bond	Anl.v.15(46)
DE0001030567	Inflation-indexed bond	Anl.v.15(26)
DE0001030559	Inflation-indexed bond	Anl.v.14(30)
DE0001030542	Inflation-indexed bond	Anl.v.12(23)
DE0001102333	Nominal bond	Anl.v.2014 (2024)
DE0001102325	Nominal bond	Anl.v.2013 (2023)
DE0001102317	Nominal bond	Anl.v.2013 (2023)
DE0001102309	Nominal bond	Anl.v.2013 (2023)
DE0001135499	Nominal bond	Anl.v.2012 (2022)
DE0001135481	Nominal bond	Anl.v.2012 (2044)
DE0001135473	Nominal bond	Anl.v.2012 (2022)
DE0001102366	Nominal bond	Anl.v.2014 (2024)
DE0001102358	Nominal bond	Anl.v.2014 (2024)
DE0001102341	Nominal bond	Anl.v.2014 (2046)
DE0001102531	Nominal bond	Anl.v.2021 (2031)
DE0001102523	Nominal bond	Anl.v.2020 (2027)
DE0001102515	Nominal bond	Anl.v.2020 (2035)
DE0001102549	Nominal bond	Anl.v.2021 (2036)

Table A.1.: German bonds