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How Money relates to value? An empirical examination on Gold, Silver and Bitcoin*

José Alves† João Quental Gonçalves‡

Abstract

The present work offers a review on two divergent schools of thought regarding the subject of money and highlights why understanding it is important to grasp the workings and nature of the concept of money. We adopt a spontaneous order perspective on social institutions, considering money as one. Such framework allows for the construction of axioms from which we formulate our problem allowing us to ask how old forms of money such as Gold and Silver hold up in today's world regarding their hedging properties. Moreover, we also do so for Bitcoin since we consider it an appropriate asset due to its specific characteristics and its (at the time of writing) more than 10-year life span. We resort to the Autoregressive Distributed Lag (ARDL) methodology in order to study our three assets in the context of the US dollar and the US Economy for two different time periods. We analyse price dynamics from 1980 to 2020 for gold and silver resorting to annual data. Regarding bitcoin we employ quarterly data from 2009 to 2020. We conclude that the theories that explain what money is, how it comes to be so and how certain types of "money assets" may serve both as an indirect hedge against inflation in the two interpretations of the word and as a "stock of value" have merits that might deserve further investigation.

Keywords: Money; Inflation; Gold; Silver; Bitcoin
JEL Codes: B25; D46; E42; E51

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1 Introduction

Replying to the questions "what is money?" and "how does it come to be so?" has long been attempted by many throughout history yet, as will be discussed along the development of the present work, there seems to be no satisfactory unifying definition that can be agreed upon in the field of economics suggesting that many take for granted an item whose functions are more complex than being just a mere medium of exchange. The implications of a poor understanding of the functions of money has consequences both on the private and on the public dominions that guide the economic actions of the everyday individual. There are two main views on money, one that interprets it as being a purposelessly designed state creation and another that sees it (as well as the state) as a social institution derived from the spontaneous order of human action and interaction. From these two, the latter allows us to build a robust framework that is able to incorporate the former within it. This approach based on a spontaneous order view whose implicit process of discovery is built upon a fundamental notion concerning the concept of value. Yet, not all concepts of subjective value are the same and Menger's approach must be highlighted in order to, together with the concept of marginal utility explain what money is and how it comes to be so. Alongside this approach, Gresham's law and Cantillon's effect must be put into proper context for they play a determinant role in illustrating why adulterations in the quantity of money may have perverse effects on wealth transfer and, necessarily on its distribution. From here, the two different concepts behind the word "inflation" become clear and their distinction essential to formulate both the problem and the question discussed in the present work. In order to reply to our question on how might an individual use old and new forms of money in his favour. We use Gold, Silver and Bitcoin through the use of the autoregressive distributed lag (ARDL) cointegration technique offsetting their prices against some of their asset specific variables together with others that represent the economic cycle for the USA. We conclude that gold and silver show short-run "stock of value" properties relative to rising debt and falling real GDP, yet the long-term effect only stand for the gold-debt relation. The current work will have the following structure, in section two we present the chosen literature summarizing the theoretical and empirical contributions to our topic. In section three we discuss the methodology used and in section four we present and discuss our results. Section five contains the concluding remarks for our work.

2 Related Literature

From the two mains views on money, we start from the view that interprets it as being a state creation is known as Chartalism, (alternatively known as The State Theory of Money) it was coined and developed by Knapp (1924) in 1905 and although, as Rallo (2020) points out, Knapp was not a Chartalist himself, the aforementioned Knapp's work still serves as the intellectual foundation for the political guidelines popular in the global bastions of Ideolog-

ical Bureaucracy (see, for instance Krause (1968) and Mises (1944) for more on Ideological Bureaucracy), from representatives and leaders of the main Central Banks, to the International Monetary Fund (IMF), the United Nations, the World Bank and growing areas of academia who favour a "Debtism" perspective called Modern Monetary Theory (MMT). Although, from a monetary and fiscal standpoint, proponents of Chartalism have disagreements, they all seem to agree or at least concede that money is a policy tool just like any other, conceived through the form of a token monopolistically owned and created by the state (see the compilation made Battilossi et al. (2020)) on the multiple Chartalist views about the nature of money and its origins). Chartalists tend to misappropriate or even fully reject methodological individualism (Schumpeter (2017) coined the term in 1908 while discussing what he believed to then be the most robust framework for the study of social phenomena). Economists of this proclivity who study the subject of money will necessarily develop theories that help them sustain a narrative supported by carefully selected historical facts and convenient treatment of empirical evidence that corroborates the view on money as an instrument of government bureaucratic design and control, that way developing a narrative that tries to adjust the origins and nature of money to the findings of historians and anthropologists.

Alternatively, through careful observation of the market process, Carl Menger developed his theory of subjective value Menger (1950) putting forward not only a logical solution to the paradox of value but also, through it pointing out inconsistencies behind the Smithian-Ricardian-Marxist "cost of production" theories of value and prices (although with different nuances between them, the general idea is consistent among them; Smith (1776), Ricardo (1891) and Marx (2011) theories of value are the most prominent), that wrongly equated the relative price of goods to the its "cost". In other words to the relative quantity of "effort", i.e., labor (more generally adding other inputs) put into their production leading to the possibility of dubious interpretations of market activity and gains from trade has being based on exploitation and zero-sum relations .

Unfortunately, when discussing how individuals make choices it is not uncommon to put forward Menger, Walras and Jevons as proponents of the same subjective value and marginalist ideas. Jaffé (1976) discusses why this proposition is incorrect providing insight on why Menger's views are not necessarily compatible with the other two's. This incompatibility stems from both making concessions in order to fit their views on utility into mathematical models including the mistake of unlike Menger, taking prices and not value as the central focus behind their explanations for market dynamics. This led them to make dubious assertions imposing equivalence between the same quantities of goods that happened to share the same prices. This equivalence implies objectivity in value for these specific goods, making it inconsistent with a "pure" theory of subjective value.

Understanding Menger's theory of value is necessary to understand how he constructed his 1892's theory of money (Menger (2009)). Money's value, just like any other tradable asset, stems from the coincidence of the subjective valuations that agents make of specific goods

having greater or lesser marketability (probability of being accepted as means of indirect exchange). Menger's views fall within a "spontaneous order" interpretation of how social institutions evolve, this assertion is strengthened not only through his views on value and money but also on the work of those who followed in his footsteps (see, for instance, the works of von Böhm-Bawerk, von Wieser, von Mises, Oskar Morgenstern, Murray Rothbard, von Hayek, Israel Kirzner, and as discussed by Durnin (2017) to a lesser extent, James M. Buchanan being some of the most well-known).

Menger's theory of subjective value proposes a useful explanation on how things (including the intangible such as ideas) are valued by economic agents and how, out of their contrasting valuations, exchange takes places, how that exchange sends signals to the market and how from those signals, prices are formed. Different agents value the same things in different ways this happens because utility is not in things themselves but is transferred by the individuals upon them through the expectations they form on the hypothetical usefulness they may derive from their "consumption". This notion is important because it shows why trade is not a zero-sum game. If two agents value the same item differently, and the holder values it in less amount of agreed upon tradable assets than the potential buyer, assuming the tradable assets are held and that they intent to perform a trade, both have a "winning" outcome, since the seller acquired tradable assets he valued more than the item and the buyer got an item he valued more than the tradable assets he gave up for it. Notice how the same relative price for the goods does not imply equivalent value between them, this happens because, assuming that the expectations that led to the trade were met, reversing the trade would let both at a "loss" according to their original valuations meaning that, value-wise they are not necessarily equivalent. Moreover, quantity contextually available plays a determinant role on how much tradable assets each agent is willing to give or receive for other tradable assets they deem useful such as the aforementioned item. This is why a diamond can potentially be valued as "little" as a glass of water for someone who is lost in a desert and yet, for the average individual this proposition would seem nonsensical. This is the law of marginal utility at work.

It can be safely stated that the focus of Menger's essay is firstly on value and only then on prices, the same cannot be said for Walras' nor Jevons' efforts. Hence, Menger (1950)'s Subjective Theory of Value not only proposes a sound solution to the Paradox of Value but it also effectively refutes the existing multiple "cost of production" (objective) theories of value presented by different authors, as (Moss 2010, p.270) points out: "...Menger attacked what he understood to be the major doctrinal position held by the classical school - that the cost of production of capital goods in either labor or money terms has some special power over current market valuations".

Regarding money, Menger (2009) explanation for how it becomes so, and through this process, for what it is, can be summarised as follows. Individuals engage in barter exchange if, as previously explained they both expect to benefit from trade. The expectations are formed according to their subjective valuations of the goods up for exchange. When doing so they

will find that barter exchange has a potential shortcoming, if there is not a double coincidence of wants, i.e., if one of the agents doesn't desire the goods the other has to offer, then only through indirect exchange can the trade follow through. This process of search and discovery will lead agents to constantly engage in indirect exchange in order to fulfil their wants (this assuming that they are able to find suitors who desire their goods at all). Different individuals will try different goods in this intermediary role. Individuals will imitate each other by using goods that better perform the intermediary role and rejecting those that are not as marketable. With time, only a handful of goods will remain and those are what can be described as money. This technical evolution of money is important because it allows for further specialization and division of labour. If an individual has confidence in a generally accepted means of indirect exchange, he can focus on producing a less diverse set of goods in a higher quantity through specialization.

As such Menger concludes that "Money is not an invention of the state. It is not the product of a legislative act. Even the sanction of political authority is not necessary for its existence" (Menger 1950, p.261-262) yet, sees room for a potential beneficial role of the state, asserting that "the sanction of the state gives a particular good the attribute of being a universal substitute in exchange, and although the state is not responsible for the existence of the money-character of the good, it is responsible for a significant improvement of its money-character" (Menger 1950, p.262).

The aforementioned intermediary goods that have the potential to be money have characteristics that differentiate them from other goods as appropriate media of exchange, making some more fitting than others. According to (Bagus 2009, p. 24), Rothbard names five, "commodity money is in heavy demand, highly divisible, portable, durable, and has a high value per unit weight". (Bagus 2009, p. 24) also states that Melotte and Moore "claim that a good money must be divisible, portable, durable, and stable" (Bagus (2009) assertions are based on Rothbard (1983) and Melotte & Moore (1995)). Furthermore, Jevons (1876) names seven : Utility and value, portability, indestructibility, homogeneity, divisibility, stability of value and cognizability.

We found that we are better able to explain them the following way: Recognizability, in order for a good to be able to serve as a medium of exchange, it must be recognizable by a sufficient number of agents as serving the purpose of intermediary in trade; Homogeneity and Divisibility, these two go together because one leads to another, homogeneity in a good means that one unit of a good can be divisible by smaller units that, upon adding, equate to the same purchasing power of the original unit, this is important because it explains for instance, why gold makes for a better intermediary of exchange when compared to a diamond. As as such, divisibility is effective to the extent that the good is homogeneous; Portability, although connect to Divisibility and to Durability, portability stands on its own. In trade being able to carry around a medium of exchange is paramount to its intermediary function; Durability, if an item lasts longer, it has a clear advantage over others that have a higher chance of deterio-

rating making goods that are more impervious to wear and tear a better medium of exchange; Storability, although apparently redundant due to it being a derivative characteristic of the previously mentioned, it still serves as a differentiating factor. In fact, some cryptocurrencies are presented as having an advantage over other alternative money assets due to their ability to be stored without the need for an intermediary, this is considered as an advantage by their users. Moreover, Gold is denser than Silver which would transmit the former an advantage over the later independently of quantity available.

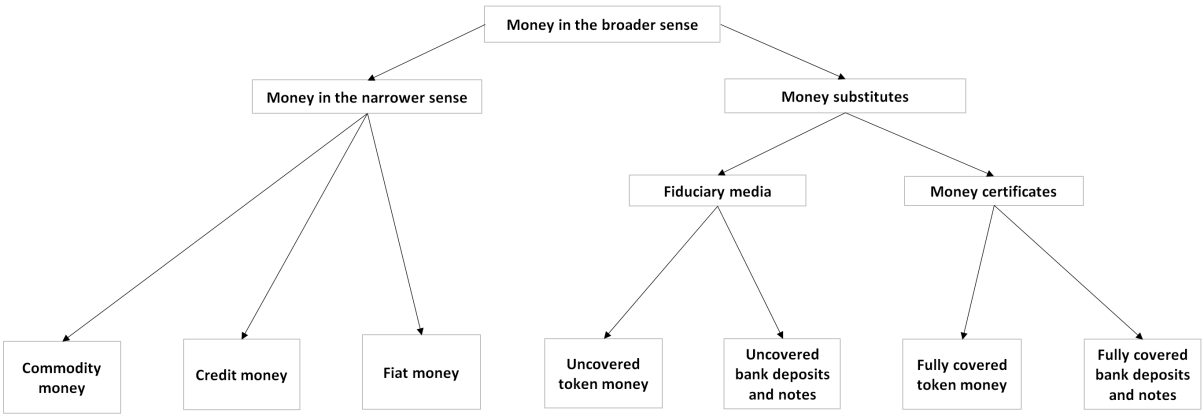
Notice that relative quantity is left out. As explained when discussing the subjective nature of value, quantity available determines the potential for an item to be granted intra-temporal "value" or serve as an inter-temporal "stock of value", scarcity being related to higher valuations whereas abundance being related to lower valuations. This psychological phenomenon can be further explored through the concept of marginal utility, the less one has available, the more one values it. Yet, this phenomena of scarcity associated with the more marketable commodities will eventually drive them out of circulation since they are valued more as a "stock of value" than as a medium of exchange. Individual's will tend to save the scarcer marketable commodities spending the less scarce in their day-to-day purchases.

Balch (1908) advances that this relation was first independently observed by three authors: Oresme, Copernicus and Gresham (by chronological order). Still, it is the former who is given more recognition regarding this phenomenon. Known as "Gresham's law", it proposes that relative quantity is a determining factor in money's ability to remain in circulation, this happens not only in relation to the quantity of money but also to the purity of the circulating currency. As an early attempt at a "quantitative theory of money" the three author's differently describe the common trend of how debased currency ("bad money") inundated the markets while currency containing a higher degree of purity ("good money") exited them. Menger was aware of this phenomenon and highlight how money does not need to be a measure of value nor a stock of value to be money itself, "...the functions of being a "measure of value" and a "store of value" must not be attributed to money as such, since these functions are of a merely accidental nature and are not an essential part of the concept of money"(Menger 1950, p. 280), therefore, since quantity available affects agents' valuations, a fitting commodity that both serves as a medium of exchange and is scarce does in fact fill the role of stock of value. Gold, and to a lesser degree, Silver serve as classical illustrations of the aforementioned relation. As will be discussed later, cryptocurrencies, specifically Bitcoin, may have the potential to become contemporaneous illustrations.

What then, are the functions money must perform to become and remain so? von Mises, a proponent of Menger's ideas, advances in his treatise on Money (Mises (1980)) that different characteristics of money in the broader sense serve different purposes, and therefore, make for different types of money (see Figure 1). As such, only three groups of assets are considered to be money in the narrower sense: Commodity money - commodities whose main function in trade coincides with the purpose of expediting indirect exchange; Fiat money - legally enforced

commodities imposed but not necessarily broadly accepted (Mises claims that the legal authority can only control the quantity issued but not its usage) as medium of exchange whose importance is derived from the stamp and not from the underlying commodity that caries it; Credit money - claims on a commodity (money or otherwise) that are due in the future and whose price varies independently of the underlying asset it covers (probability of redemption and date of redemption are price determinants independent of the commodity itself). Moreover, Mises advances that there are substitutes of the aforementioned types, "When an indirect exchange is transacted with the aid of money, it is not necessary for the money to change hands physically; a perfectly secure claim to an equivalent sum, payable on demand, may be transferred instead of the actual coins." (Mises 1980, p.50). Yet, Mises stresses the important fact that being substitutes does not make them equivalent to money. Underlying asset and claim upon it are distinct concepts. Mises calls these types of money, "money substitutes" and proposes that the functions of money do not carry equal weight. Therefore, being a medium of exchange (not only for the buying of goods but also in serving as collateral and means of payment of debts), being a stock and being a measure of value are not of equivalent importance as such, he points out the important detail that there might be more claims on money (the aforementioned substitutes) than the amount of money that effectively exists, if the claim is fully covered they can be considered "money certificates" if not they are called "fiduciary media". Mises explains: "If the money reserve kept by the debtor against the money-substitutes issued is less than the total amount of such substitutes, we call that amount of substitutes which exceeds the reserve fiduciary media."(Mises 1996, 433). The money substitutes, together with the previously mentioned fiat and credit money, constitute almost all of the money (in the broader sense) existing in today's world. Nowadays, money supply measured by the monetary aggregates M2 and M3 serve as illustrations of this concept. In conclusion, the essential function of money is indirect exchange. Only this qualifies something as money yet, there are other recognizable functions and characteristics that allows one to differentiate value-wise between types of money.

Figure 1: Mises' Money Diagram[1]



[1]Diagram built using as reference the schematics provided under Appendix B of Mises (1980).

So far an explanation for what money is and how it becomes so has been provided yet, to answer how it evolves from one stage to another further commentary is required. Menger attributes money's purchasing power to the fact that it is demanded and explains that it is demanded because it possesses purchasing power in other words agents accept money because they expect others to accept it too. In detail, Kiyotaki & Wright (1991) used this rational as the basis from which they develop their model on how and why agents use and accept a medium of exchange in trade. Mises notices the circularity in this reasoning and introduces time as a determinant factor in this process, yesterdays' trades determine prices (including of money itself), agents carry this memory to today's market decisions and valuations. Today's market decisions and valuations are carried to tomorrow's and so on. Together with this phenomenon and as previously discussed, Menger's proposition of commodities whose characteristics make them be used, saved and traded both for their use value and exchange value is accounted for, following along the cycle we end up with a small number of commodities (possibly even a single commodity) whose high marketability make them the commonly used intermediary of exchange, i.e. money, and whose demand necessarily surpasses its industrial uses since, by becoming money its usage as a commodity loses utility for most consumers. For instance, historically, when ingots were turned into coins the large majority sought them for their "money" use and not for their industrial use. This theory of how a commodity comes from having its value updated to its usefulness beyond industrial demand along time is called the "regression theorem" and was first proposed by Mises, following Menger's work, in The Theory of Money and Credit (Mises (1980)).

How then do we distinguish between the two currents of thought? Chartalists, depending on the branch of their multiple ramifications, tend to interpret money as being either Credit money and/or Fiat money and/or Fiduciary media. Since they interpret money as a policy tool they therefore, might reject Money certificates as being an effective tool and commodity money as either not being money at all or as a "barbaric relic", this conclusion is reached because both imply quantity constrains on Central Banks' ability to influence the money supply. As for those of the spontaneous order interpretation of social phenomena, commodity, credit and fiat money can be considered money (or money in a narrower sense), the rest being substitutes. The insistence on having mentioning money's quantity before can now be put into useful context for the current framework. Menger's followers sustain that the quantity of money affects its price in relation to itself in an inter-temporal context, i.e. the purchasing power of money goes down as its relative quantity rises. They call this phenomenon of expansion in the relative quantity of money as inflation unlike most economists (see Bryan et al. (1997)) who interpret inflation in its modern meaning as being simply a rise in the general price level.

The "Cantillon Effect" hypothesis Cantillon (2015) that, as discussed in Sieroń (2019), Thornton (2019), Hagemann & Trautwein (1998) and Alves & Silva (2021), among others, uncovers how a rise in the quantity of money has different impacts on different tiers of society in real terms and as such, has the potential to generate and amplify inequality of wealth and

income serves as an example of why the word inflation original meaning is important.

The way in which new money is created means that individuals who own more assets can absorb new liquidity first and in higher quantity due to their higher level of available collateral. This creates an arbitrage scenario in which those who get the new liquidity and in higher quantity first lose none to very little purchasing power and those who get to the new liquidity later and in lower quantity do so when its effects on the purchasing power are already underway. The "Cantillon Effect" hypothesis fully explores this phenomena and its impact on inequality of wealth and income. Moreover, the effect of adulterations in the quantity of money has further consequences, one of the most intuitive being its effect on individual consumption and saving decisions. Expansionary policies will lead to a potential loss in the purchasing power of money. In fact, and taking opportunity costs into consideration if the money supply grows in a one-to-one proportion with the quantity of goods and services, there is necessarily a loss because letting the quantity of money unadulterated would mean it would be worth relatively more of it self today. If the purchasing power of money is decreasing and individuals expect the condition to remain, they have a real incentive to spend in present consumption instead of saving for future consumption. This will lead to a rise in the price level. Discussing why the large majority of macroeconomists, politicians and central banks' chairmen are obsessed with inflation (regarding the rise in price level sense of the word) is beyond the scope of this work. Yet, in accordance to the findings of Bordo et al. (2004), they seem to be oblivious to the fact that deflation can be a result from, and result in better living standards. In what regards to most macroeconomists, the problem seems to stem from their over-reliance on empirical models whose data selection is biased by 20th century events, leading them to associate economic growth with a rise in the price level. Selgin (1997) further develops how a deflationary economy can grow. Moreover, Mincer & Danninger (2000) and Lv et al. (2019) discuss the deflationary impact that technology growth has in the economy where productivity gains from technological progress reduce production costs letting firms produce any combination of higher output and/or lower prices. This suggests a "war" between the artificial pumping of money to sustain an arbitrary price level and the natural effect of technology that pressures the price level down. For the day-to-day individual, it is a war on the purchasing power of his money.

In an environment where the mix of fiat and credit money together with fiduciary media constitute the large majority of money, what other types of money-like assets should private individuals chose in order to protect the output of their time, effort and skills? Under the framework proposed, the goal of our work is then to provide an answer to the above question through the form of three assets in relation to the US dollar. Two have history on their side, the last was unironically devised in a way that its purchasing power cannot be endogenously adulterated. Gold, Silver and Bitcoin will be discussed for their potential to serve as an answer to the problem at hand. The US dollar was chosen as the monetary reference because it is broadly considered the global reserve currency (see Costigan et al. (2017) and Iancu et al. (2020)) as such, the US market will also serve as point of reference.

Regarding gold as being an alternative to the government issued currencies, it is traditionally associated with being an hedge against inflation. Moreover, it is the most common asset to be brought forward when speaking of commodity money and it is owned by Central Banks worldwide and institutions like the IMF. Gold not only fills all the requisites previously discussed in order for a commodity to become money but also has added to it the fact that there are natural constraints on its supply. This factor together with an increasing world population and expansion in the quantity of non-commodity money, make the market for gold one where demand grows higher than supply, this allows for gold to be considered a scarce commodity. In such context, gold has the necessary characteristic to be an inter-temporal stock of value, therefore, necessarily an hedge against the loss in the purchasing power of money. Adding to this is the fact that apart from the jewellery industry, the majority of the demand for gold is done for investment purposes, both private (financial markets) and public (Central Banks), something consistence with the regression theorem whereby one commodity that serves as an appropriate medium of exchange will have the main force behind its demand from being a medium of exchange and not for its industrial use. Moreover, it is also consistent with Gresham's law since being a stock of value will turn gold into a saving asset largely reducing its role as a circulating medium of exchange. An interesting data-point is the fact that the United States became a net importer of gold for the first time since 2020, adding an amount of 52 tons to its total (see (*Mineral commodity summaries 2021* 2021, p.70); whether gold is an inter-temporal stock of value therefore, implicitly being an hedge against inflation has been a relevant topic in the literature for quite some time).

In order to discuss this proposition the following author's inputs were taken into account (see O'Connor et al. (2015))s: Jaffe (1989) regressed the return on gold with the changes in CPI for the period between 1971 and 1987, he found a positive relation between the price of gold and movements in the price level although he points out the significance is very small; Naser (2017) takes Bodie (1976) (Bodie's focus was on the minimum variance point along the efficient portfolio frontier concluding that an hedge against inflation is any security that reduces the variance of the real return of a nominal risk-free bond) definition of what type of security can be considered an inflation hedge and uses Fisher's equation (see Fisher (1930)) under a rational expectations' framework for US monthly data from 1986 to 2016, employed into an error correcting model (ECM) developed by Johansen (1988) and Johansen & Juselius (1990) in order to examine the long and short term relationship between gold's returns and inflation as measured by the CPI for all urban consumers. His findings suggest gold is not a short-term hedge against inflation but that it can be so for investors willing to hold gold for longer periods; Murach (2019) used quarterly data for thirteen countries (The EU was taken as a country for monetary purposes) from 1980 to 2013. By applying a multivariate cointegration (CVAR) analysis, he found that there is a positive long-run relationship between global liquidity and the price of gold, where the author defines "global liquidity" as the difference between money in a broader sense and nominal GDP, . Moreover, he found positive co-movement between gold

prices and inflation for the period; Kaufmann & Winters (1989) finds a model that correlates well with gold's yearly price levels for the period of 1974-88. This author concludes that metric tonnage output in gold production correlates negatively and so does the the dollar index. Moreover, he also finds that the GNP deflator used to measure inflation correlates positively with the gold price level; Building on the Kaufmann-winter's model, Elfakhani et al. (2009) reviewed it for the same period and tested it for the period 1971-1998 getting similar results. Additionally, they tried to upgrade the model with more variables but were unsuccessful due to the presence of multicollinearity among some of the variables; McCown & Zimmerman (2006) studied monthly gold prices for the period of 1970-2003, using the capital asset pricing model and found that gold's beta was indifferent from zero with returns slightly higher than the Treasury Bill rates. Moreover, he used the arbitrage pricing model and found gold clearly qualifies as an hedge against inflation. Moreover, he found that the time series of Gold and that of the Consumer Price Index (CPI) for the US are cointegrated, reinforcing his previous findings on gold being an hedge against inflation; Adrangi et al. (2003) tested two alternative hypothesis on gold prices for the period of 1968 and 1999, the Fama (1981) and Geske & Roll (1983) hypothesis, where given that the demand for gold can be divided between industrial and financial demand, gold may not be affected negatively by inflation, unlike corporate profits and stock prices, and the Feldstein (1983) hypothesis, where he assumes that the demand for gold is a function of its expected real after-tax retuns, taking this as given he develops a portfolio equilibrium model that suggests that gold behaves as an inflation hedge. They found there was a positive relation between expected (but not unexpected) inflation and real gold returns, concluding gold is a hedge against inflation; Bampinas & Panagiotidis (2015) investigated the long-run edging ability of gold through its annual prices against different CPI measures for the US and the UK from 1971 to 2010. They used a time invariant and a time-varying cointegration framewor, and found gold to have a good long-run hedging performance against headline, expected and core CPI Inflation yet, this effect is larger in the US than in the UK; Van Hoang et al. (2016) used non-linear autoregressive distributed lags (NARDL) developed by Shin et al. (2014) for a monthly dataset of gold prices and the CPI for a total of six countries from 1955 to 2015. They found gold not to be an inflationary hedge in the long run for any of the countries however, in the short-run gold was found to actually be an inflationary hedge for India, the UK and the US; Batten et al. (2014) use monthly data for the period 1985-2012, they apply cointegration tests based on Johansen (1991) single equation error correction model. Moreover, they also use Saikkonen & Lütkepohl (2000) conclusions on the superiority of tests based on adjusted series for the cointegrating rank of VAR in order to account for structural breaks. Also, they employed a Kalman filter based approach in their regression, founding no cointegration between the price of gold and the CPI, with Gold's betas being decreasingly small for the 1990's. Yet, they also find Gold's betas to significantly rise throughout the 2000's, suggesting different conclusions for different time spans. In sum, most of the literature seems to agree on gold's ability to serve as an inflationary hedge for the US dollar. The disagreements

seem to stem from the time period and methodology chosen.

In what concerns to silver and just like gold, silver also has the features needed for a commodity to become money and due to its natural natural constraints on supply (although to a significant lesser extent than gold). In 2020 the domestic uses for silver were distributed as follows (see (*Mineral commodity summaries 2021* 2021, p.150)): 28% - for electrical and electronics use; 26% for jewellery and silverware; 19% for coins and medals; 3% for application in photography; 24% for other purposes. This is consistent with the common notion that silver's industrial demand has a much larger share in total silver demand than that it has for total gold demand.

The literature on Silver (see, for instance, Vigne et al. (2017)) is more remote than that for gold yet, we were able to find the following author's inputs: The previously mentioned Bampinas & Panagiotidis (2015) article on gold also examined silver for the same period and methodology. They found silver not to be an hedge against inflation in the US although, they found a strong positive long-run relationship for the UK; Bilgin et al. (2018) used linear and non-linear cointegration tests for white precious metals, including silver for the period 1988-2016. Silver was found not to be an effective hedge against inflation for most countries, including the US; As with Bampinas & Panagiotidis (2015),s Adrangi et al. (2003) also tested silver's ability to be an effective inflationary hedge. Using the same data and methods they did for gold, they found that real prices for silver allowed it to be considered an inflationary hedge since its returns are not negatively affected by inflation. The literature on silver's ability to hedge inflation is inconclusive yet, it seems to suggest that silver fails to do so for the US dollar.

Regarding Cryptocurrencies, this considered asset is a subset of virtual currencies that in turn are themselves a subset of digital currencies as such, under the guidelines that serve as basis for our framework, at first glance they seem not to be money in the narrower sense. Unlike gold and silver, cryptocurrencies are not commodity money in the traditional sense. Moreover, they are not fiat money (they are not legal tender imposed by an authority). Additionally, if in the future there happens to be a national currency issued in the form of a crypto currency, this proposition will no longer hold. They are not credit money (there is no underlying asset backing them). More specifically, if a central bank decided to issue legal tender in form of a cryptocurrency, it could fit MMT's definition of money as state issued debt (see Wray (2015)).

As for the broader definition of money they are not fully covered nor uncovered bank deposits nor notes, leaving us with two sub-categories. Cryptocurrencies might be tokens, meaning that they can either be fiduciary media, money certificates or both. Crypto tokens could possibly fit these criteria and any cryptocurrency designed to hold fungible (homogeneous) properties would as well. Alternatively, they might be defined as a form of fiat money that is not imposed by a central authority, rather it becomes naturally accepted (which would imply the need to call it another name distinctive from fiat). This could be consistent with the Menger-Mises Money theory apart from the important distinction that it didn't begin as a commodity

nor was it imposed by any central authority. Finally the argument for a digital commodity could be made which would fit crypto currencies as money in the narrower sense almost perfectly well within our framework, apart from the fact that they still didn't begin as traditional commodities, rather were created to serve a purpose without industrial demand ever being a factor.

Discussing exactly how each of cryptocurrency fits in Mises' Money Diagram or is consistent with the regression theorem is beyond the scope of this work (see, for instance, Davidson & Block (2015), Stroukal et al. (2018),Luther (2018) and Pickering (2019)). It seems to us that depending on the specific protocols behind each crypto currency, each might fit significantly different categories under Mises' Money Diagram. Moreover, the fact that most crypto currencies are still in their early stages of adoption would reduce the strength of any empirical results regarding their stock-of-value and inflation hedging potential abilities. As such, we must focus on the particular case that might offer the best change at arriving at relevant conclusions. We find Nakamoto (2008) adaptation of timechain technology (that later came to be known as blockchain) to conceptual money the most appealing, not only because of the time span available for analysis but also due to the fundamental characteristics it has that sets it apart from others. There is a finite number of Bitcoin in total (21 million minus the ones that were lost meanwhile) which gives it potential to be considered a scarce asset, this is important because it is consistent with what constitutes a potential stock-of-value. Moreover, it works in a decentralized manner, meaning that besides the inability to create more, no central authority can influence it endogenously, this is also important because it offers strength to the stock-of-vale hypothesis. Furthermore, this also might be interpreted to qualify it as having the characteristics needed to be considered a form of digital commodity, its "industrial demand" being replaced by its "technical demand". Finally it does not need a traditional banking system to operate, offering its users the ability to be store it either in "cold storage" or in exchanges of their choice. Regarding the ongoing back and forth debate about safety, environmental, network security or if it is an effective form of money among other issues surrounding Bitcoin and other cryptocurrencies, they are also beyond the scope of our study (regarding the discussion surrounding Bitcoin's effectiveness as money see for instance, Ammous (2018), Allen et al. (2020), Stroukal et al. (2018), Balvers & McDonald (2021), Grinberg (2012) and Schilling & Uhlig (2019)). Discussing its ability to be an inter-temporal stock-of-value through its potential to serve as an inflationary hedge is our aim.

The literature on the topic is scarce yet, we were able to find one article that fits our framework: Blau et al. (2021) study the lead-lag relation between Bitcoin and the Fed of St. Louis' 5-year forward inflation expectation rates. Their data uses daily prices between the period of January 1st, 2019 and December 31st, 2020 for the US. They found that Bitcoin's returns are positively correlated with the future inflation expectation rate and tend to lead it. Unexpected increases in Bitcoin's price where showed to be associated with "a significant and persistent" increase in the forward inflation expectation rate, suggesting Bitcoin's ability to serve as an

inflation hedge. As there is too little literature on bitcoin's ability to serve as an inflationary hedge, the discussion is so far inconclusive. Therefore, our study, despite providing a new analysis on gold's and silver's ability to serve as an inflationary hedge, aims at contributing to the literature concerning cryptocurrencies, specifically the Bitcoin, as an alternative inflation hedge against the US dollar.

3 Empirical Framework

3.1 Data

We study how the growth in money supply impacts the evolution of three different assets price-wise. We consider gold, silver and bitcoin has having the potential to offset the deterioration of U.S. Dollar's purchasing power. Moreover, we analyse these relationships in the context of the U.S. market. Due to data availability and inter-temporal pertinence the data employed in our study covers the years between 1980 and 2020 for gold and silver and from 2009 to 2020 for bitcoin. This way we are able to cover a period that had five major recessions including the first year of the SARS-CoV-2 pandemic. Regarding gold's data, we use the price in U.S. Dollars per Troy Ounce (Au_{Price}) from Handy & Harman through Thomson Reuters (Eikon (2021)), the gold mine production in metric tons ($Au_{Prod,US}$) and the gold reported consumption in metric tons ($Au_{Cons,US}$) both from a combination of the U.S. Geological Survey's (USGS) Mineral 2021 Gold commodity summary(*Mineral commodity summaries 2021* (2021)) and the USGS's Historical Statistics for Mineral and Material Commodities in the United States (Kelly et al. (2017)). For silver, we use its price in U.S. Dollars per Troy Ounce (Ag_{Price}) from Handy & Harman through Eikon (2021), the silver mine production in metric tons ($Ag_{Prod,US}$) and the silver apparent consumption in metric tons ($Au_{Cons,US}$) also both from a combination of the U.S. Geological Survey's (USGS) Mineral 2021 Silver commodity summary (*Mineral commodity summaries 2021* (2021)) and the USGS's Historical Statistics for Mineral and Material Commodities in the United States (Kelly et al. (2017)). Regarding Bitcoin, we use its price in U.S. Dollars per unit ($Bitcoin_{Price}$) and the total supply of bitcoins ($Bitcoin_{Prod}$) provided in Blockchain.com's website under currency statistics[2]. Unlike gold and silver and due to the short life span of bitcoin as an asset we have chosen to use quarterly data. Moreover, also unlike gold and silver, data on Bitcoin's supply is readily available on a quarterly basis. We also used certain control variables for gold and silver on an yearly basis and for bitcoin on a quarterly basis: the Producer Price Index for all commodities (PPI), the Money Stock ($M2$) in Billions of Dollars, the real GDP in Billions of Chained 2012 Dollars (GDP) and the stock of federal government debt ($Debt$) in Millions of Dollars, all of them provided by the Federal Reserve Economic Data (FRED) from the Federal Reserve Bank of St. Louis (St. Louis Fed). With the exception of PPI, all the remaining variables are taken in logarithmic form.

[2] https://www.blockchain.com/prices/

In tables I and II we report the summary statistics for the variables employed to study the annual dynamics of gold and silver prices, and for the variables used to assess how quarterly bitcoin prices behave, respectively. In tables III, IV and V we report the respective correlation matrices for the above-mentioned variables.

Table I: Summary statistics for the variables used in Gold and Silver analysis, annual data, 1980-2020.

Variable	Mean	Std. Dev.	Min	Max	Obs
AU_{Price}	6.348	0.612	5.615	7.543	41
AU_{Prod}	5.307	0.631	3.408	5.903	41
AU_{Cons}	5.312	0.207	4.99	5.778	41
AG_{Price}	2.191	0.652	1.322	3.518	41
AG_{Prod}	7.214	0.24	6.839	7.687	41
AG_{Cons}	8.603	0.245	8.089	8.987	41
$M2$	8.57	0.667	7.378	9.859	41
GDP	9.41	0.322	8.825	9.865	41
$Debt$	15.622	0.928	13.743	17.139	41
PPI	76.564	19.858	49.446	106.484	41

Table II: Summary statistics for the variables employed regarding Bitcoin, quarterly data, 2009M01 - 2020M12.

Variable	Mean	Std. Dev.	Min	Max	Obs
BTC_{Price}	5.811	3.177	-2.778	10.27	42
BTC_{Prod}	16.091	0.866	13.016	16.738	48
$M2$	9.752	0.074	9.625	9.865	48
GDP	16.713	0.22	16.262	17.152	48
$Debt$	30.112	0.233	29.764	30.622	48
PPI	103.235	4.889	91.776	114.022	48

The Correlation matrices show results pertinent to our analysis. Regarding the Price of gold, mine production shows correlation with the price, this makes sense since the yearly flow quantity tends to represent a relatively small portion of the overall gold stock. The intuition behind consumption is not as straight forward, if it is true that a rise in demand would drive the price up, it is also true that fall in price would drive demand up due to the substitution effect between "stock of value" and "safe haven" demand against Industrial demand, below certain price levels industrial demand takes over. The strong positive relation with the price index and the M2 money aggregate is highly relevant to our premise. The positive relationship between debt and gold is also important yet, there is a caveat, gold is traditionally used not only as an edge against the loss in the purchasing power of money ("stock of value") but also to protect one-self from a general crisis ("safe haven") such as a market crash or government debt default.

Mostly, what is said for gold can be replicated for silver although, unlike that for gold, silver's consumption has a positive relationship with its price. The intuition here is that rising prices represent a buy signal to silver's investment demand that, although representing a smaller

share of its total demand, still has a significant weight in determining silver's price, offsetting eventual drops in industrial demand. Moreover, the negative correlation between price and production can be attributed to silver's industrial demand having a much larger share in the total demand for silver than that it has for gold.

Bitcoin is a different case; it has a short history not allowing for robust conclusions. The positive relationship with its production is of interest though and can be attributed to the fact that supply rises at a decreasing slower pace due to the halving process and price discovery, meaning that a rising unrestrained demand happens alongside a constraint diminishing rise in supply. Moreover, having a fixed quantity set at 21 million units together with a process of price discovery still taking place today are relevant contextual factors contributing to the positive relation discussed. Regarding the PPI and its relationship with BTC's price is almost non-existent, this is explained by the fact that, unlike its physical commodities counterparts, BTC has no industrial demand yet, we still decided to use the PPI together with BTC instead of using the more recurrent methods of general price measure such as the CPI or the CPIU. We did so because besides the usual causes of price adjustment lags on behalf of the producers when they are faced with rising costs of production (such as menu costs, competition and inflation expectations) there is still the shrinkflation (Corless (2019); Ochirova (2017)) phenomenon distorting the usefulness of the two aforementioned indexes. Said distortions should be minimized or non-existent with the PPI.

Table III: Correlation matrix for yearly data employed in Gold analysis.

Variables	AU_{Price}	AU_{Prod}	AU_{Cons}	$M2$	GDP	$Debt$	PPI
AU_{Price}	1						
AU_{Prod}	0.005	1					
AU_{Cons}	-0.776	0.418	1				
$M2$	0.798	0.484	-0.428	1			
GDP	0.694	0.59	-0.289	0.977	1		
$Debt$	0.747	0.599	-0.338	0.985	0.98	1	
PPI	0.885	0.365	-0.565	0.964	0.93	0.947	1

Table IV: Correlation matrix for yearly data employed in Silver analysis.

Variables	AG_{Price}	AG_{Prod}	AG_{Cons}	$M2$	GDP	$Debt$	PPI
AG_{Price}	1						
AG_{Prod}	-0.754	1					
AG_{Cons}	0.401	-0.366	1				
$M2$	0.614	-0.473	0.732	1			
GDP	0.523	-0.37	0.746	0.977	1		
$Debt$	0.544	-0.37	0.703	0.985	0.98	1	
PPI	0.756	-0.549	0.666	0.964	0.93	0.947	1

Table V: Correlation matrix for quarterly data employed in Bitcoin's analysis.

Variables	BTC_{Price}	BTC_{Prod}	$M2$	$Debt$	GDP	PPI
BTC_{Price}	1					
BTC_{Prod}	0.958	1				
$M2$	0.913	0.813	1			
GDP	0.906	0.857	0.928	0.989	1	
$Debt$	0.905	0.787	0.926	1		
PPI	-0.011	0.575	0.314	0.322	0.407	1

3.2 Methodology

Our empirical approach enables us to assess the long-run impact between the prices of each asset (gold, silver and bitcoin), monetary supply and other relevant variables as the production and consumption of each asset, the production price index, the U.S. GDP and its Federal Debt. Therefore, we resort to the Auto Regressive Distributed Lag (ARDL) - bounds test approach for cointegration analysis as proposed in Pesaran et al. (1995) and Pesaran et al. (2001). This approach overcomes the methodological disadvantages of Engle & Granger (1987) and Johansen & Juselius (1990), since they require that in order to proceed with a cointegration analysis, the series have to be of the same order of integration, when Pesaran et al. (1995) and Pesaran et al. (2001) allow for I(0) and I(1) time series variables in the same estimated regression. Furthermore, a regression estimation based in the Engle & Granger (1987) approach may lead to biased results in finite samples as the ones employed in our study caused by omitted short-run dynamics and as concluded in Banerjee et al. (1986).

Therefore, we first assess the stationarity properties of each series through the Ng & Perron (2001) unit root test which, when compared to other unit root tests, has the advantage of providing robust results for smaller samples. We present in tables VI and VII the unit root tests results on an annual, for Gold and Silver analyses, and on a quarterly basis, for Bitcoin analysis. We conclude that all the asset prices are non-stationary at levels but stationary in first-differences, i.e, those series are integrated of order 1 (I(1)), and the same rationale is applicable to the both Gold and Silver production and consumption series, the GDP, PPI and the Debt. Only the Money Supply series, represented by M2, are stationary in levels (I(0)). In this sense, these findings are in accordance with the above-mentioned requirements to apply an ARDL approach.

We set our ARDL model in the following general way:

$$\Delta Y_t = \beta_0 + \theta_1 Y_{t-1} + ... + \theta_{t-p} + \beta_{i0} X_{it} + ... + \beta_{ip} X_{it-p} + \varepsilon_t \tag{1}$$

where Y_t, β_0, X_i, p, ε_t represent each asset price (Au_{Price}, Ag_{Price} and $Bitcoin_{Price}$), the constant term, the set of explanatory variables, the lag length, and the error term, respectively. Note that regarding the Bitcoin analysis we do not include the consumption of this asset since it does not make economic sense.

With our empirical specification, it can be rewritten to define the short run dynamics as well as the cointegrated vector, as specified in 2:

$$\Delta Y_t = \alpha_0 + \sum_{p=1}^{n-1} \gamma_p \Delta Y_{t-p} + \sum_{p=0}^{n-1} \sigma_{1p} \Delta X_{1t-p} + \sum_{p=0}^{n-1} \sigma_{2p} \Delta X_{2t-p} + ... + \sum_{p=0}^{n-1} \sigma_{kp} \Delta X_{kt-p} + \lambda ECT_{t-1} + \varepsilon_t \tag{2}$$

where σ_{ki} and ECT_{t-1} are the short-run impacts of each explanatory variable in price dynamics, and the error correction vector, respectively. The Error Correction Term is given by $ECT_{t-1} = Y_{t-1} - \sum_{i=1}^{k} \omega_i X_{it-1}$ and it captures the adjustment process of each asset price in the long-run, as well as, the speed of adjustment, if exists. Lastly, the long-run estimates for each explanatory variable are given by ω_i.

In order to proceed with the optimal lag length selection of each one of our three models, and based in the studies conducted in Anderson et al. (1998) Burnham & Anderson (2004), we concluded that to resort to Akaike Information Criteria was the best selection method to employ in our study.

Based in AIC criteria, we obtained an ARDL (2,3,3,3,3,3,1) model for study Gold prices dynamics, and ARDL (3,1,3,1,2,3,1) model for Silver prices and, lastly, an ARDL (4,5,5,0,5,2) model for Bitcoin prices.

We present in table VIII the results regarding the cointegration tests for each model we used. As can be seen, all the models evidence a long run relationship between each asset price and the respective explanatory variables at least a 95% level of significance. In fact, all the results obtained for the F-statistic are greater than both I(0) and I(1) bounds which led us to conclude for a cointegration among the variables.

3.3 Models diagnosis

In order to check for potential issues that may lead to invalid estimations of our above-mentioned models, we have proceeded with several diagnosis tests. Firstly, we have performed a Breusch-Godfrey Serial Correlation LM test to analyze if each one of our models evidenced serial correlation problems. In fact, a rejection of the null hypothesis of this test would let us to conclude that a given model presents serial correlation which makes the model estimations no longer valid. The same is true regarding the heteroscedasticity problems. As recognized, the existence of heteroscedasticity makes that the variance does not remain stable, which makes for estimation outputs that are inefficient and biased. In this sense, and in order to ensure that each of our model results are robust, we have proceeded with a Breusch-Pagan-Godfrey heteroscedasticity test to each model. Additionally, we also performed a RESET test to each model to verify if there is misspecification in any one of our models. If we reject the null hypothesis a given model is considered to be misspecified. The results for the serial correlation, heteroscedasticity and Ramsey misspecification tests are presented in tables IX, X and XI,

Table VI: Ng & Perron (2001) unit root tests results for each annual series.

Variable	Level, intercept				Level, intercept and trend			
	MZa	MZt	MSB	MPT	MZa	MZt	MSB	MPT
Au_{Price}	-0.404	-0.195	0.484	17.017	-3.325	-1.178	0.354	25.21
Au_{Prod}	-1.008	-0.638	0.633	20.929	-2.253	-0.921	0.409	33.958
Au_{Cons}	-4.248	-1.418	0.334	5.824	-5.316	-1.597	0.3	17.018
Ag_{Price}	-2.321	-0.997	0.43	10.02	-3.812	-1.318	0.346	23.04
Ag_{Prod}	-3.374	-1.262	0.374	7.238	-4.592	-1.467	0.32	19.49
Ag_{Cons}	-6.087*	-1.529	0.251	4.675	-14.728*	-2.706*	0.184	6.229
$M2$	-1.338	-0.473	0.354	10.67	-23.594**	-3.287**	0.139***	4.728**
GDP	0.284	0.184	0.647	28.991	-4.858	-1.334	0.275	17.526
$Debt$	-4.428	-1.235	0.279	5.936	-14.191	-2.655*	0.187	6.471*
PPI	1.138	1.143	1.004	71.891	-5.67	-1.677	0.296	16.057
1% critical value	-13.8	-2.58	0.174	1.78	-23.8	-3.42	0.143	4.03
5% critical value	-8.1	-1.98	0.233	3.17	-17.3	-2.91	0.168	5.48
10% critical value	-5.7	-1.62	0.275	4.45	-14.2	-2.62	0.185	6.67
Variable	1st Differences, intercept				1st Differences, intercept and trend			
	MZa	MZt	MSB	MPT	MZa	MZt	MSB	MPT
Au_{Price}	-4.803	-1.379	0.287	5.46	-16.813*	-2.898*	0.172*	5.43**
Au_{Prod}	-1.345	-0.659	0.49	14.186	-16.043*	-2.814*	0.175*	5.787*
Au_{Cons}	-19.455***	-3.104***	0.16***	1.311***	-19.403**	-3.1**	0.16**	4.788**
Ag_{Price}	0.138	0.091	0.655	28.658	-17.136*	-2.925*	0.171*	5.333*
Ag_{Prod}	-13.829***	-2.621***	0.19**	1.805**	-17.538**	-2.94**	0.168**	5.324**
Ag_{Cons}	-19.3***	-3.01***	0.156***	1.608***	-19.449**	-3.069**	0.158**	4.984**
$M2$	-9.598**	-1.641*	0.171***	4.428*	-12.379	-1.859	0.15**	10.354
GDP	-16.216***	-2.684***	0.165***	2.105**	-17.861**	-2.844*	0.159**	5.952*
$Debt$	-8.582**	-1.904*	0.222**	3.472*	-9.483	-1.907	0.201	10.663
PPI	-19.125***	-3.088***	0.161***	1.298***	-19.169**	-3.095**	0.161**	4.759**
1% critical value	-13.8	-2.58	0.174	1.78	-23.8	-3.42	0.143	4.03
5% critical value	-8.1	-1.98	0.233	3.17	-17.3	-2.91	0.168	5.48
10% critical value	-5.7	-1.62	0.275	4.45	-14.2	-2.62	0.185	6.67

Note: Ng-Perron statistic values for each variable. Each variable is labeled with *, ** and *** to denote 10%, 5% and 1% significance level, respectively. Number of lags chosen by Akaike Information Criteria (AIC).

Table VII: Ng & Perron (2001) unit root tests results for each quarterly series.

Variable	Level, intercept				Level, intercept and trend			
	MZa	MZt	MSB	MPT	MZa	MZt	MSB	MPT
$Bitcoin_{Price}$	0.756	0.602	0.796	44.465	-5.773	-1.66	0.288	15.713
$Bitcoin_{Prod}$	0.792	21.213	26.8	42994.5	-1177.52 ***	-24.256 ***	0.021 ***	0.087 ***
$M2$	0.866	0.713	0.824	48.168	-17.458 **	-2.93 **	0.168 **	5.367 **
GDP	2.431	3.558	1.463	183.146	-4.026	-1.332	0.331	21.634
$Debt$	2.59	2.19	0.845	67.255	-22.729 **	-3.076 **	0.135 ***	5.714 *
PPI	-0.884	-0.498	0.564	18.639	-4.254	-1.441	0.339	21.256
1% critical value	-13.8	-2.58	0.174	1.78	-23.8	-3.42	0.143	4.03
5% critical value	-8.1	-1.98	0.233	3.17	-17.3	-2.91	0.168	5.48
10% critical value	-5.7	-1.62	0.275	4.45	-14.2	-2.62	0.185	6.67
Variable	1st Differences, intercept				1st Differences, intercept and trend			
	MZa	MZt	MSB	MPT	MZa	MZt	MSB	MPT
$Bitcoin_{Price}$	-15.547 ***	-2.713 ***	0.174 **	1.862 **	-30.053 ***	-3.857 ***	0.128 ***	3.145 ***
$Bitcoin_{Prod}$	0.5258	2.87431	5.46651	1689.64	-41.078 ***	-4.51 ***	0.11 ***	2.337 ***
$M2$	-66.312 ***	-5.749 ***	0.087 ***	0.389 ***	-76.525 ***	-6.186 ***	0.081 ***	1.191 ***
GDP	-5.04141	-1.57850	0.31311	4.88384	-6.60947	-1.72902	0.26160	13.8454
$Debt$	-2.28674	-0.96484	0.42193	10.0147	-2.25685	-0.72901	0.32302	26.6337
PPI	-39.953 ***	-4.406 ***	0.11 ***	0.792 ***	-48.875 ***	-4.935 ***	0.101 ***	1.909 ***
1% critical value	-13.8	-2.58	0.174	1.78	-23.8	-3.42	0.143	4.03
5% critical value	-8.1	-1.98	0.233	3.17	-17.3	-2.91	0.168	5.48
10% critical value	-5.7	-1.62	0.275	4.45	-14.2	-2.62	0.185	6.67

Note: Ng-Perron statistic values for each variable. Each variable is labeled with *, ** and *** to denote 10%, 5% and 1% significance level, respectively.Number of lags chosen by Akaike Information Criteria (AIC).

Table VIII: Cointegration Bound test results for each model

			Critical values by level of significance							
	k	*F-statistic*	I(0) 10%	I(1) 10%	I(0) 5%	I(1) 5%	I(0) 2.50%	I(1) 2.50%	I(0) 1%	I(1) 1%
Gold	6	7.321	2.12	3.23	2.45	3.61	2.75	3.99	3.15	4.43
Silver	6	6.633	2.12	3.23	2.45	3.61	2.75	3.99	3.15	4.43
Bitcoin	5	6.121	2.26	3.35	2.62	3.79	2.96	4.18	3.41	4.68

respectively. Although, and as we can observe, our models have no serial correlation (with the exception of Gold), no heterokedasticity and, lastly, there are no evidences of misspecification for any of our models.

Table IX: Breusch-Godfrey Serial Correlation LM test results for each model

	df	*F-Statistic*	*p-value*
Gold	$F_{(3,31)}$	3.493	0.0272
Silver	$F_{(3;31)}$	1.300	0.292
Bitcoin	$F_{(3;33)}$	2.002	0.133

We recognize that model stability is a major concern in ARDL analysis since the parameters‘ stability may change across the timespan considered. Therefore, we have proceeded with the Brown et al. (1975)'s CUMSUM test which is based on the cumulative sum of the recursive residuals. We have also performed the CUSUM squared test which is based on the recursive

Table X: Breusch-Pagan-Godfrey Heteroscedasticity test results for each model

	F	*F-Statistic*	*p-value*
Gold	$F_{(1,39)}$	0.61	0.439
Silver	$F_{(1,39)}$	1.64	0.208
Bitcoin	$F_{(1,40)}$	1.94	0.172

Table XI: Ramsey RESET test results for each model

	F	*F-Statistic*	*p-value*
Gold	$F_{(3,31)}$	0.270	0.845
Silver	$F_{(3,31)}$	2.56	0.073
Bitcoin	$F_{(3;33)}$	2.37	0.088

squared residuals. The need to perform the aforementioned test is justified by the greater accuracy it provides regarding the analysis of stability in our models. As can be observed in figure 2, the cumulative sum of the recursive residuals and the recursive squared residuals both lie between the upper and lower bounds (5% of significance) which evidences the existence of stability on our three models.

Until now we have tested for possible existing econometric problems in our models, we concluded that they were suitable to develop.We can now proceed with the long-run relationship analysis between the variables employed in each model, by resorting to the bounds test proposed in Pesaran et al. (2001). With this test, it is possible to assess if there arecointegration relationships among the variables. Beside the fact that this test can be used independently of the order of integration of the regressors, as mentioned earlier, two other advantages of this test arise when compared to other similar tests: one that is related to the fact that that the results obtained for the long-run model estimations are found to be unbiased (Harris & Sollis (2003)) and another feature related with the higher efficiency in small and finite samples.

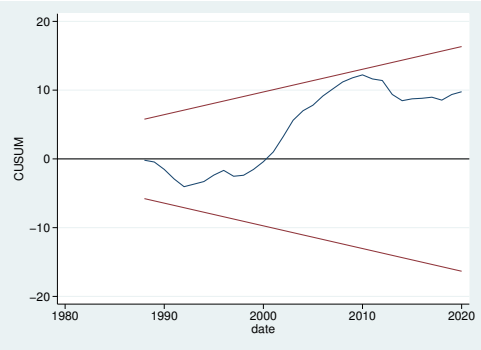
4 Results

In order to summarize our results into useful insights we must divide our analysis in two frameworks, the short-run and the long-run, for three assets each, Gold, Silver and Bitcoin. The obtained results for our ARDL models are presented in table XII.

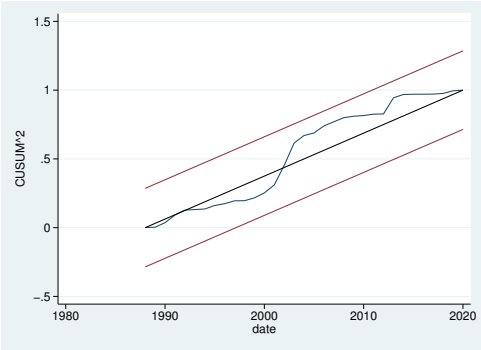
4.1 Gold

Regarding our short-run results, a positive change in production shows a positive relation with price. The intuition is that rising quantity produced in the short term, anticipates traditional factors investors associate with a rising price of gold (rise in the general price level and/or market crashes). Expected rise in future prices is itself anticipated by producers who start

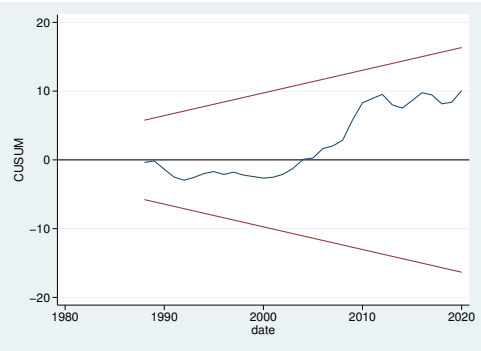
Figure 2: CUSUM and CUSUM squared graphs for each model



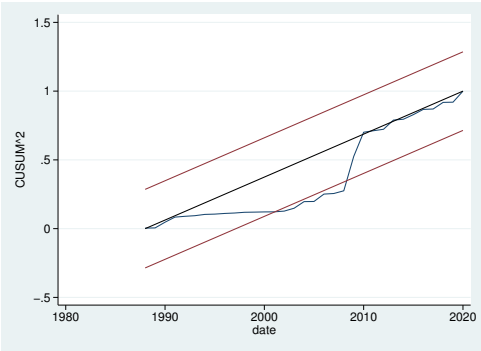
(a) Gold CUSUM test



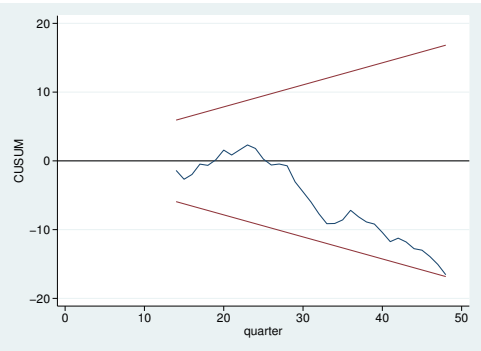
(b) Gold CUSUM squared test



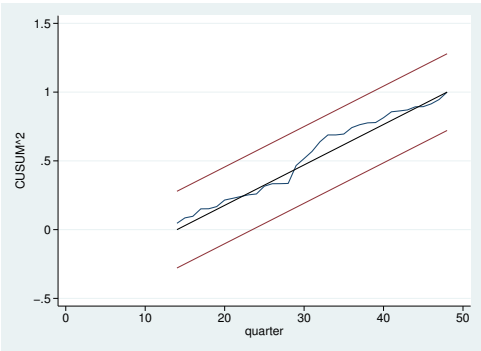
(c) Silver CUSUM test



(d) Silver CUSUM squared test



(e) Bitcoin CUSUM test



(f) Bitcoin CUSUM squared test

Table XII: Estimated results for Gold, Silver and BTC ARDL models.

		Gold	*Silver*	*BTC*
λ		-0.863***	-0.225	-1.361***
		(0.246)	(0.317)	(0.273)
		Long-Run		
$Prod$		-0.894**	-0.888	-2.06
		(0.31)	(1.839)	(12.717)
$Cons$		-0.279	-5.353	-
		(0.8)	(8.3)	-
$M2$		-1.565*	2.701	34.899
		(0.854)	(4.226)	(33.789)
GDP		2.029	16.035	-21.446
		(1.655)	(27.032)	(22.843)
$Debt$		1.681***	-1.319	11.218
		(0.547)	(2.095)	(11.543)
PPI		-0.013	-0.167	0.145**
		(0.018)	(0.348)	(0.064)
		Short-Run		
$Price$	t	0.232	-0.113	0.092
		(0.155)	(0.23)	(0.247)
	$t-1$		0.261	0.027
			(0.202)	(0.172)
	$t-2$			0.265
				(0.172)
$Prod$	t	0.929***	0.775**	-23.23
		(0.299)	(0.332)	(30.199)
	$t-1$	0.426		-52.136*
		(0.325)		(26.608)
	$t-2$	1.139***		13.881
		(0.349)		(15.468)
	$t-3$			-47.317*
				(22.068)
	$t-4$			2.286
				(28.914)
$Cons$	t	-0.049	0.751*	
		(0.498)	(0.426)	
	$t-1$	-0.102	0.801**	
		(0.289)	(0.354)	
	$t-2$	-0.757***	0.416	
		(0.238)	(0.312)	
$M2$	t	0.364	2.626*	-17.959
		(1.068)	(1.435)	(38.539)
	$t-1$	0.683		-12.34
		(0.972)		(34.029)
	$t-2$	-2.676**		-10.995
		(1.01)		(39.343)
	$t-3$			-15.758
				(40.789)
	$t-4$			-39.059
				(38.233)
GDP	t	-5.898**	2.559	41.604
		(2.06)	(2.668)	(24.812)
	$t-1$	-1.766	-7.679**	35.852
		(1.267)	(2.914)	(22.74)
	$t-2$	-2.498		21.828
		(1.431)		(19.122)
	$t-3$			5.764
				(18.339)
	$t-4$			-6.95
				(13.806)
$Debt$	t	-1.426	-1.575	
		(1.013)	(1.491)	
	$t-1$	-0.829	4.499**	
		(0.788)	(1.548)	
	$t-2$	3.256***	4.686**	
		(0.902)	(1.951)	
PPI	t	0.017	0.022	-0.106
		(0.011)	(0.021)	(0.089)
	$t-1$			-0.01
				(0.076)
Obs.		38	38	37
Adjusted R-Squared		0.766	0.608	0.611

producing today in order to supply future demand (and implied rising gold prices) in one or two years: The mining, refining, molding, certification and transportation processes are lengthy and not manageable in a few days nor weeks' time specially in commodities whose industrial demand does not hold the larger share in its total demand. Regarding consumption, a positive trend anticipates by two periods a fall in gold prices, again, like in the production case, the result is counter intuitive and suggests that in the short-term gold consumers do not anticipate price movements accurately. Regarding the Money Supply as measured by M2, the result is apparently surprising, a rise in the quantity of money in a two period time anticipates a fall in future gold prices, this might be explained by two factors, first is the fact that rising M2 is the result of policies meant to expand economic growth as such, when and if such growth happens, investors tend to look for assets that pay dividends and/or interest while diminishing the "safe havens" in their portfolio. Moreover, as discussed previously, the Cantillon effect takes place, whereby financial markets are the most reactionary to new money being created, meaning a rise in security prices. Secondly, we must look at the reverse repo market that lets us know that not all money being created by the Central Banks's purchasing process is absorbed by financial markets nor by the general economy as a whole. Money supply measured by not considering what portion of it comes into the market and at what time is a poor indicator for short term anticipation of asset's real prices. Rising Real GDP's negative relation to the price of gold is straightforward, rising confidence and rising returns from securities make them more attractive to own than gold, investment funds tend to diminish their exposure to gold and other gold-like assets in order to increase their exposure to securities, Moreover, commodities whose industrial demand represents the larger share in their total demand also become more attractive since they show procyclical trends. The opposite happens when Real GDP falls, gold prices rise more than proportionally. Rising Debt has a significant more than proportional positive impact on golds' price. For the short-run this, together with the inverse more than proportional relation between gold and Real GDP, makes for a strong empirical backing to the remark that gold is a "safe haven". Yet, nothing significant may be concluded for its ability to serve as a hedge against the loss in the purchasing power of money on a straightforward direct relation with the quantity of money as measured by M2 nor with the price index as measured by the PPI.

The long-term results are as follows, long term rise in production equates lower gold prices, unlike in the short-term, this framework allows for quantity demanded and supplied to adjust to one another, and the traditional supply-demand market dynamics come into play, suggesting accurately that markets take time to adjust. The relationship with money supply as measured by M2 stands, suggesting that either gold is not an edge against the loss in the purchasing power or that, as previously discussed M2 is a poor measure of the real quantity of circulating currency and substitutes ergo of their total quantity relative to the total amount of goods and services. Moreover, no significant results were found in relation to the PPI. The relationship with real GDP falls yet, with rising debt it remains. The logic here is that movements in real GDP as a way of anticipating short-run economic trends do not translate to the long-term framework yet,

debt's do so.

4.2 Silver

In the short-run, production shows a similar trend to that of gold. Unlike that of gold however, growth in consumption shows a positive relation with growth in silver's price suggesting that the supply-demand dynamics are present in the short-run and that the investment demand offsetting trend is in effect. Moreover, unlike gold's, silvers' industrial demand represents the larger share of its total demand meaning that its short-term demand better anticipates its current and near future price. Money supply as measured by M2 has a more than proportional positive impact in silver's price, this can be explained by the fact that growth in M2 is known to precede positive economic cycles and industrial demand rises with positive economic cycles moreover, investors are known to associate growth in M2 with rising prices and silver is one of the most sought-after assets in such instances. Real GDP's growth has a one period negative relationship with silver, this might be explained by the fact that investors tend to reduce their exposure to gold and gold-like assets (where silver falls under) in order to pursue other more lucrative endeavours. This interpretation suggests that in the short run, a fall in investment demand offsets the rise in industrial demand. Rising Debt has a positive relation with the rise in the price of silver potentially showing silver as having short-term attributes similar to those of gold. In the long-run no conclusive results were achieved for silver.

4.3 Bitcoin

As expected, bitcoin's short "life span" does not allow for robust conclusions and our model yields results that are for the most part inconclusive regarding this asset. In the short-run rising production is associated with diminishing price suggesting short-term demand-supply dynamics present. However, the curious relationship found is one with a parameter that did not show (surprisingly) any relation to the other two assets. The PPI shows a less that proportional positive relationship with bitcoin's price suggesting that for the time period studied bitcoin was the only one of the three assets that showed hedge-like behavior regarding the loss in the purchasing power of the dollar both through rising prices and shrinkflation. Yet, this relation only stands in the long-run and in a less than proportional faction.

Regarding what modern day economists call inflation (rise in the general price level) and the older meaning of the word (a relative expansion in the quantity of money), we opted to illustrate the former with the PPI and the later with the money supply as measured by M2. Other authors chose very different approaches to interpreting what is what and what measures what as can be seen in our literature revision. Therefore, we cannot state that gold and silver hold by any means short nor long-run hedging properties yet, they do show a behavior consistent with that of a stock of value relative to Debt and to Real GDP. As is well-known, modern-day policy approaches to economic crisis have been dealt with an expansion in their respective central

banks' balance sheet assets together with an expansion of national debt. This should not be a polemic statement. This fact implies that within the constraints of our model and the variables chosen to measure the economic concepts proposed, gold and silver indirectly may still hold hedging properties since they rise in price with factors that anticipate an expansion in money supply. Moreover, bitcoin shows a direct relation, even if less than proportional, with the PPI suggesting that, regarding the modern day meaning of inflation, it does hold hedge like properties for the period observed.

5 Concluding remarks

Our paper aims at contributing to a better understanding of what money is, how it becomes so, how its functions affect not only its type but also its overall market value and how quantity and specific attributes give certain types of money the ability to transition into becoming something else entirely. Our framework is based on a specific interpretation of economics history that we feel better reflects reality.

We review how authors ideas and analysis contributed to our understanding of the origins and nature of money, moreover we also share our interpretation of important insights they brought forward such as money types, functions and properties and how market dynamics are present and affect the price of money though a conjugation of the referred insights.

Through this process we formulate a question on what other types of money should private individuals choose in order to protect the output of their time, effort and skills. We chose variables that we feel better translated the different concepts of economic measure and deferred to tradition and innovation regarding the considered money types in order to answer our proposed question.

Under such context we study Gold, Silver and Bitcoin and test for the claims that they may constitute a hedge against the loss in the purchasing power of the US dollar though the means of an ARDL model. Our findings are largely inconclusive to this regard due to a potential misuse of M2 as a measure of money supply (done on purpose due to the common narratives that relate the two), the non-existent relation with PPI and possibly model fitting issues. However, the results are quite conclusive on gold's and silver's ability to serve as a "stock of value" in the sense that they react negatively with real GDP and positively with public debt in the short-term and that gold keeps its por-cyclical relation with debt in the long term. Regarding Bitcoin the main relation found was with PPI, suggesting it may possibly serve as a "hedge" but less than proportionally so against the rise in prices measured by that indicator.

As previously suggest in the discussion of our results real GDP and debt have a direct impact on M2 as such the indirect relation between the two traditional commodity money assets stands. This is consistent with our discussions regarding the ability to adulterate quantity as a way of diminishing a medium of exchange's ability to serve as a potential sock of inter-temporal value. Moreover, this is also consistent with our analysis of how Gresham's law explains the eventual

long-term behavior of gold and might serve as an empirical backed vindication based on long-term results for central banks and edge funds to keep holding gold in their balance sheets. Also, it gives positive signals to an eventual answer to our question. In this context we can confidently state that holding bitcoin in the long-run offsets less than proportionally the loss in the purchasing power of money as measured by the PPI and that gold and silver do so indirectly through their short-term "stock of value" attributes in relation to both debt and real GDP with gold keeping its relationship with debt in the long-run. Such conclusions highlight the merits behind the theories discussed throughout the present work, and we hope help inspire further research that provides empirical backing to the analysis of defunct economists whose work has intemporal relevance to an accurate understanding of human action and interaction.

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