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IMPACT OF DIFFERENT ECONOMIC SHOCKS ON GOLD PRICE DEVELOPMENT

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Master Thesis

Study Program:	Finance Financial Markets and Investing
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Affidavit

I hereby honestly declare that I have prepared the final master's thesis independently and I have listed all the literature used in the appropriate place. With my signature, I confirm this fact and at the same time the fact that the printed version of the final master's thesis is identical to its electronic version.

In Bratislava on 02.05.2024 Bc. Dominik Kucbel

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A B S T R A C T

KUCBEL, Dominik: *Impact of different economic shocks on the gold price development.* – University of Economics in Bratislava. Faculty of Economics and Finance; Department of Banking and International Finance. University of Pavia. Department of Economics and Management. – assoc. prof. Ing. Jana Kotlebová, PhD., assoc. prof. Claudia Tarantola, PhD. – Bratislava, Pavia: FEF EUBA, DEM UNIPV, 2024, 96 p.

The master thesis is developed on the topic of impacts of various economic shocks on the gold price development. The aim of the master's thesis was to identify, select, quantify, and evaluate the impacts of various economic shocks on the price of gold and its volatility, stemming from the market environment. In this thesis we analyzed selected gold's price existing and potential determinants and examined their impact on the gold spot price trough short-run Autoregressive Distributed Lag model. The individual parts of the thesis were focused on approaching the issue of economic shocks affecting gold's price through the lens of existing academic research done on the topic of interest and stating the current development of the issue, selection of potential eligible variables for the research and their categorization, and the research itself with the interpretation of the results. The result of the thesis is the acceptance and rejection of the established hypotheses regarding specific gold's price shock originators, and confirmation of the well-established directions for the relationship among gold and its various determinants. In this thesis we provide a comprehensive view into the approach of the short-run Autoregressive Distributed Lag modelling and the model's construction, its critical inference, refinement, and interpretation of the estimated results. Moreover, we provide helpful information for the investors and public sector in regard to the potential benefits stemming from the gold acquisition.

Key words: gold, economic shocks, gold's price determinants, short-run ARDL model, impact of shocks

A S T R A T T O

KUCBEL, Dominik: *L'impatto di shock economici sul prezzo dell'oro.* – Università di Pavia. Dipartimento di Scienze Economiche e Aziendali. Università di Economia di Bratislava. Facoltà di Economia; Dipartimento di Banca e Finanza Internazionale. – Prof. Claudia Tarantola, PhD., doc. Ing. Jana Kotlebová, PhD. – Pavia, Bratislava: DSEA UNIPV, FE EUBA, 2024, 96 p.

La tesi di master è stata sviluppata sul tema dell'impatto di vari shock economici sull'andamento del prezzo dell'oro. L'obiettivo della tesi di master è stato quello di identificare, selezionare, quantificare e valutare gli impatti di vari shock economici sul prezzo dell'oro e sulla sua volatilità, derivanti dal contesto di mercato. In questa tesi sono state analizzate le determinanti esistenti e potenziali del prezzo dell'oro e si è esaminato il loro impatto sul prezzo spot dell'oro attraverso un modello di lag autoregressivo distribuito a breve termine. Le singole parti della tesi si sono concentrate sull'approccio alla questione degli shock economici che influenzano il prezzo dell'oro attraverso la lente della ricerca accademica esistente sull'argomento di interesse e sull'attuale sviluppo della questione, sulla selezione delle potenziali variabili ammissibili per la ricerca e sulla loro categorizzazione, e sulla ricerca stessa con l'interpretazione dei risultati. Il risultato della tesi è l'accettazione e il rifiuto delle ipotesi stabilite in merito alle cause specifiche dello shock del prezzo dell'oro e la conferma delle direzioni consolidate per la relazione tra l'oro e le sue varie determinanti. In questa tesi forniamo una visione completa dell'approccio alla modellazione autoregressiva a lag distribuiti di breve periodo e della costruzione del modello, della sua inferenza critica, del suo perfezionamento e dell'interpretazione dei risultati stimati. Inoltre, forniamo informazioni utili agli investitori e al settore pubblico in merito ai potenziali benefici derivanti dall'acquisizione dell'oro.

Parole chiave: oro, shock economici, determinante del prezzo dell'oro, modello ARDL a breve termine, impatto degli shock

C O N T E N T

The list of illustrations, tables and used abbreviations

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ADF – Augmented Dickey-Fuller
ANFCI – Adjusted National Financial Conditions Index
ARDL – Autoregressive Distributed Lag
BoE – Bank of England
BoJ – Bank of Japan
BTC – Bitcoin
BWS – Bretton Woods System
CBGA – Central Banks Gold Agreement
CBOE – Chicago Board Options Exchange
DCC – Dynamic Conditional Correlation
DNSI – Daily News Sentiment Index
ECB – European Central Bank
EPU – Economic Policy Uncertainty
EPU – Economic Policy Uncertainty
ESDC – European Sovereign Debt Crisis
ETF – Exchange Traded Fund
FED – The Federal Reserve System
GARCH – Generalized Auto Regressive Conditional Heteroskedasticity
GAS – Generalized Autoregressive Score
GDP – Gross Domestic Product
GEPU – Global Economic Policy Uncertainty
GFC – Global Financial Crisis
GGT – "gold" in Google Trends
GNP – Gross National Product
GPR – Geopolitical Risk
IMF – International Monetary Fund
LBMA – London Bullion Market Association
LED – Light-emitting Diode
MIDAS – Mixed Data Sampling
OZ – Ounce
PC – Partisan Conflict
PP – Phillips-Peron
QE – Quantitative Easing
QQ – Quantile-on-Quantile
RC – Rolling Correlation
SDR – Special Drawing Rights
UK – United Kingdom
USA, US – United States of America
USD – United States Dollar
VAR – Vector Autoregression
VIF – Variance Inflation Factor
WGC – World Gold Council
ZLB – Zero Lower Bound

Introduction

Gold has perplexed humanity since the distant ancient times. Due to its superb qualities, it successively worked its way into our daily lives in various forms. Initially, as a part of jewelry, its shine and scarcity reflected societal status, and with it, came its value. As a durable, noncorrosive, extremely well malleable metal, with great divisibility characteristics, people recognized it as a store of value, and used it for this purpose ever since. Besides its wide usage in jewelry and economics, it is also an important commodity for medicine and technology and plays crucial role in the advancements within these spheres.

Gold is also considered as an asset, the so-called safe haven of sorts, traded in billions of dollars every day. Therefore, the knowledge regarding its price development is crucial for understanding its potential and qualities, which it can provide when needed. Multiple scholars, academics and researchers sought a peek behind the curtain, where multivariate nexus of intertwined and ever-changing relationships dictate the gold's price development. State of the art methods were utilized to partially gain more and more wisdom, for the understanding and successful utilization of the benefits of gold acquisition.

Our master thesis focuses onto examination of the impacts, which gold's price determinants exert upon this shining metal. It is written according to the official guidelines of the University of Economics in Bratislava; therefore, it abides by specific structure and segmentation. Initially, we disclose the current state of research of this topic in the first chapter, then we pass on our goals and methodology of our research in chapters two and three, respectively, and consequently present and interpret the results within the chapters four and five. This master thesis offers potential not only for private subjects such as investors, but also for the public entities, whose role is to protect and enhance the public welfare in economic and financial sense. We provide statistically significant and robust results which explains more the influence of the economic shocks with their relation to the gold's price development.

We chose the topic of our master thesis because we find it utmost important to understand the value which gold can provide, and also to understand how to utilize gold as an instrument in a toolkit of every subject on the market, in order to cope with the wide variety of situations, which occur on the market every day. Due to our research, we are able to understand the potential consequences of the economic shocks resonating within the market, and how to avoid their downsides.

1 The current state of research at home and abroad

Gold has been a commodity of considerable importance for millennia. Its unique qualities of malleableness, non-corrodibility, conductivity, its mesmerizing color and glare reminiscent of the rays of the sun, together with its remarkable natural scarcity of just 0.0038 parts per million, are making this material predestined to be of great social and economic value. Although, not for all human history gold enjoyed the status of importance and wealth, it is thought that its attractiveness rose with the differentiation of societal statuses and its ingrained and partially artificially sustained scarcity.[1]

Initially used as a decorative element in jewelry and ornamental decorative items, with earliest findings from Bulgaria dating 6,500 thousand years ago gold has proven to represent the societal and hierarchical status ever since.[2] Besides this functionality, gold acquired status of financial asset, of the kind we imagine today, circa 2,500 years ago, in ancient Lydia, when first gold coins were minted on the order of king Croesus.[3] Thenceforth gold played a salient part throughout the history of trade, economics and mankind itself.

1.1 Functionality of gold

Gold enjoys substantially wide array of usage across different industries in modern world. Broadly speaking, we can differentiate between three main functions of usage: industrial function, monetary function, and investment function.[4] Each of these functions of use offer different perspective by which we can look upon this metal, however together they create complex and intertwined network of processes, which are shaping the gold's price and, to a certain extent, the direction of world's economic development.

1.1.1 Industrial function

Industrial function of gold can be further subdivided between the usage in jewelry and some minor artistic or ornamental applications, and between the usage in the technological sector, e.g. dentistry, electronics, or other industrials, according to the

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[1] SCHOENBERGER, Erica. Why is gold valuable? Nature, social power and the value of things. In *Cultural Geographies* [online]. 2011, 18.1: 3-24.
[2] KULEFF, Ivelin. ARCHEOMETRIC INVESTIGATION OF THE GOLD IN THE CHALCOLITHIC NECROPOLIS OF VARNA (5 TH MILLENNIUM BC). In *ADVANCES* [online]. 2005, 16.
[3] PAYNE, Annick. *Lydian Empire (c. 685 BCE-547 BCE)* [online].
[4] ENCYCLOPEDIA BRITANNICA. 2024. *Gold – chemical element* [online]. EB, 2024. [cited 2024-03-05]. Available on the internet: https://www.britannica.com/science/gold-chemical-element
ROYAL SOCIETY OF CHEMISTRY. 2024. *Gold* [online]. RSC, 2024. [cited 2024-03-05]. Available on the internet: https://www.rsc.org/periodic-table/element/79/gold

reporting of World Gold Council.[5] Around 50 % of world gold demand is centered around its industrial function of usage, whereas the jewelry constitutes the strong majority, of almost 88 % of demand from this point of view. In technology sector, gold is mostly used in electronics, more precisely in wireless, LED, memory, and printed circuit boards sectors, and also enjoys other industrial and decorative functionality, together with usage in dentistry.[6]

In dentistry, gold has been used for more than 4 000 years because of its favorable characteristics such as longevity, biocompatibility, aesthetics, functionality, and ease of malleability. However, there is also a widespread demand for the alternative, more cost-effective materials like titanium, cobalt or nickel-based alloys, and all ceramic crowns.[7] More recently, gold nanoparticles have been introduced within the medicinal and dentistry fields, which prove to be highly effective within their scope of application, due to gold's antibacterial and antifungal properties.[8]

In technology, or other industrials, gold, due to its superb malleability is used for printing onto various flexible substrates, for its either decorative or conductive usage.[9] The growing demand for smaller, wearable, and shape-conformable electronics propels the usage of gold for its great conductivity qualities, even under bending stress, for which gold is proven to be a right candidate. The constant advances within the research of these gold's qualities and applications enable for its highly potential use in the future in this area.[10]

Gold's usage in the jewelry industry is indisputable and as archeological evidence implies, has been for well over a thousands of years.[11] Besides representative function of social status, gold jewelry acts as a means of economic resource, which is characteristic mainly for higher carat gold accessories.[12]

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[5] WORLD GOLD COUNCIL. 2024. *Historical demand and supply* [online]. WGC, 2024. [cited 2024-03-05]. Available on the internet: https://www.gold.org/goldhub/data/gold-demand-by-country

[6] WORLD GOLD COUNCIL. 2024. *Gold Demand Trends Full Year 2023 – Jewellery* [online]. WGC, 2024. [cited 2024-03-06]. Available on the internet: https://www.gold.org/goldhub/research/gold-demand-trends/gold-demand-trends-full-year-2023/jewellery

WORLD GOLD COUNCIL. 2024. *Gold Demand Trends Full Year 2023 – Technology* [online]. WGC, 2024. [cited 2024-03-06]. Available on the internet: https://www.gold.org/goldhub/research/gold-demand-trends/gold-demand-trends-full-year-2023/technology

[7] KNOSP, Helmut et al. Gold in dentistry: alloys, uses and performance. In *Gold bulletin* [online]. 2003 Sep;36(3):93-102.

[8] BAPAT, Ranjeet A. et al. Recent advances of gold nanoparticles as biomaterial in dentistry. In *International journal of pharmaceutics* [online]. 2020 Aug 30;586:119596.

[9] BISHOP, P.T. et al. Printed gold for electronic applications. In *Gold Bulletin* [online]. 2010 Sep;43:181-8.

[10] TAKAKUWA, Masahito et al. Direct gold bonding for flexible integrated electronics. In *Science Advances* [online]. 2021 Dec 22;7(52):eabl6228.

[11] KULEFF, Ivelin. ARCHEOMETRIC INVESTIGATION OF THE GOLD IN THE CHALCOLITHIC NECROPOLIS OF VARNA (5 TH MILLENNIUM BC). In *ADVANCES* [online]. 2005, 16.

[12] MOORS, Annelies. Wearing gold, owning gold: the multiple meanings of gold jewelry. In *Etnofoor* [online]. 2013;25;79-89.

1.1.2 Monetary function

Gold's role as a monetary unit is undisputable. Throughout the history we observe the utilization of the monetary function, which this metal provides. Various factors might have created the predisposition for this characteristic, but mainly its restricted supply, great divisibility, and durability, together with deeply rooted cultural significance, led to the perception of the metal that we collectively hold today. For central banks, safety, liquidity and return qualities are the three key investment objectives.[13]

Throughout the 1980s, central banks maintained their gold reserves relatively stable, however with the onset of 1990s, CBs became net sellers of their gold reserves. The reasons were mainly due to pleasant macroeconomic conditions, while gold's safe haven aspect was not necessary, which turned CB's managers' attention towards higher return generating assets. The Central Banks Gold Agreement members continued their coordinated selling throughout the first half of the 2000s, with the attitude changing only as the result of the GFC. Consequently, the CBs became gradually net buyers of gold once again.[14]

According to the WGC, central banks continue to be net buyers globally, while cumulatively they acquired over 7,700 tons of gold over the last fourteen years.[15]

In this subsection, we disclose the origins of the monetary function of gold, together with the relationship between CBs and gold nowadays.

1.1.2.1 History of the development of the gold standard

The monetary function of gold started to be utilized from the ancient times. Throughout the world, many cultures used the gold as a means of payment, in some form, or another. Even though, with the direct usage of gold as currency comes a lot of challenges. The gold's high density causes impracticality for the movement of large volumes of the metal, paving the way for the coins made from other materials, and also the Gresham's law combined with the debasement of the currency pose a considerable issue. Nevertheless, various countries opted for adoption of the so-called gold standard, whereas the gold standard functioned on the basis of gold being the nominal anchor, with specie payments,

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[13] WORLD GOLD COUNCIL. 2024. Gold Reserves by Country [online]. WGC, 2024. [cited 2024-04-28]. Available on the internet: https://www.gold.org/goldhub/data/gold-reserves-by-country
[14] LEYLAND, Jill. The evolution in central bank attitudes toward Gold. *World Gold Council* [online]. 2010.
[15] WORLD GOLD COUNCIL. 2024. *Gold Demand Trends Full Year 2023 – Central Banks* [online]. WGC, 2024. [cited 2024-04-28]. Available on the internet: https://www.gold.org/goldhub/research/gold-demand-trends/gold-demand-trends-full-year-2023/central-banks

which enabled resumption of cash payments at parity. Given the development of the historical events, Great Britain, as the first country, adopted the gold standard in the 1821.[16]

The materialization of the first international gold standard, which is referred to as classical gold standard, occurred during the 1870s. A combination of world stage events led to this turn of events. France's loss of the Franco-Prussian war resulted into Germany's demand for the indemnity payments from France. In the meantime, Germany switched toward monetary unification based on gold, and since France was operating the bimetallic system, they had to exchange silver for gold on the world markets. Germany's switch towards gold combined with the French obligation to exchange silver for gold inherently inflated the supply of silver, so countries using bimetallic system faced potential monetary inflation. Central banks of these countries intervened by pegging the value of notes and silver coins to the price of gold. This forced the French to adopt the monometallic system in 1873.[17]

Afterwards, other countries followed, with USA securely joining the international gold standard regime in 1900 by adoption of the Gold Standard Act which effectively stated the exact parity of value for USD, therefore making gold de facto the nominal anchor also for dollar. In aggregate, the international gold standard developed during the 1870s and 1880s and continued in a certain unchanged form until the beginning of the First World War in 1914. But what is the "international gold standard"? For the gold standard as a monetary system to be international, the majority of predominant countries in the means of international trade and investments must use such a system within their domiciles, therefore the international gold standard can be considered as a result of interactions of multiple slightly different, but generally equal, domestic rules regarding such a monetary approach on an international stage. So basically, the parity of gold coin, bullion, and paper money, which was in place in key economic nations, elevated gold to the position of principal international reserve asset. Pivotal characteristic of paramount importance for the 'classical' gold standard is, that the money supply must be directly linked to the level of gold holdings of each country practicing such a monetary system, and a modification in the gold reserves ought to be succeeded by an adjustment in monetary policy.[18]

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[16] KEMMERER, Edwin Walter. Gold and the Gold Standard: The Story of Gold Money, Past, Present and Future. *Ludwig von Mises Institute* [online]. 1944.
[17] FLANDREAU, Marc. The French crime of 1873: An essay on the emergence of the international gold standard, 1870–1880. In *The Journal of Economic History* [online]. 1996, 56.4: 862-897.
[18] DAM, Kenneth W. From the Gold Clause Cases to the Gold Commission: A Half Century of American Monetary Law. In *The University of Chicago Law Review* [online]. 1983, 50.2: 504-532.

The functioning gold standard requires the following conditions to be in place: official fixed exchange rate between gold and domestic currency, free inflow, and outflow of gold in and out of the country, and the regulation of domestic currency in relation to the country's gold reserves. The stabilization of the exchange rate volatility is often times presented as a benefit of the gold standard; however, it is not straightforward. Central banks indeed had to maintain gold reserves in order to support fixed exchange rates, but the actual monetary gold-to-money ratio varied significantly among the nations, and hardly was equal to one. The exchange rate of a national currency depended upon the central bank's obligation to pay a fixed amount of gold in exchange for unit of currency. If the foreign holders of its currency demanded substantial amounts of currency to exchange for gold, it would destabilize the exchange rate to a great extent. To maintain the stability, different strategies were available for the central banks. The countries maintained either ample reserves of monetary gold and foreign exchange, or were adjusting the capital account, or made a combination of these strategies. Great Britain, despite having 10-times smaller gold-to-money ratio than France, and 4-times smaller than USA, managed its balance of payments by altering capital flows using interest rate policies. Other countries, for instance, France and Germany, utilized a combination of the strategies. Britain enjoyed this position due to its dominance on the world stage at that time. Combination of factors, mainly being the largest lender in the world, having largest share in the world trade and its financing, together with high interest earnings allowed them to shape the international monetary system to their advantage.[19]

Evident negatives of the gold standard were the vulnerability of the currency towards the fluctuation in the price of gold as a commodity, counterfeiting, inconsistency in the coinage and debasement.[20]

Perceived benefits of the adoption of the gold standard during that time were the already mentioned reduction of the exchange rate volatility, decreasement of transaction costs, positive impact on the exports, move towards better institutions, which was supposed to result into lower borrowing costs for the country, and it was also perceived as a way to align the domestic monetary policies with the prevailing global trade dynamics. The evidence from Japan, after its adoption of the gold standard in 1897, portrays slightly

[19] GUHA, Atulan. Exchange Rate Management in Gold Standard Era: A Historical Overview. In *Economic and Political Weekly* [online]. 2007, 67-72.
[20] REDISH, Angela. The persistence of bimetallism in nineteenth-century France. In *Economic History Review* [online]. 1995, 717-736.

different story. The adoption of gold standard for Japan did not effectively lower its borrowing costs, on the contrary, there is evidence of modest increase. The evidence also suggests that both silver and gold standard increased exports, at least for Japan, but this could be also attributed to the external variables affecting it, for instance, declining prices of those metals during that time.[21]

With the development of the world events, a rivalry and constantly growing series of disputes among the countries on the Old Continent, resulted into the Great War in 1914. This proposed new challenges for the international classical gold standard. As the war was nearing an end, most of the countries previously utilizing the gold standard, renounced the hard peg to it long ago. The exchanges rates were on free floating regime and high volatility was present, therefore an increasing demand for stable international monetary system with steady exchange rates grew consistently. The pre-war system offered a simple solution alternative in the form of going back to gold standard, and additionally this system demonstrably fostered commerce, financial integration, and wealth.[22]

The wartime inflation and the abandonment of the gold standard during the turmoil presented a problematic situation. Returning to pre-war parities meant risking the overvaluation of the currencies, which could lead to deflation and economic stagnation, while imposing new rates could exacerbate the global gold demand, which would undermine the trust in the new system. Nonetheless, the interwar gold standard emerged in the early 1920s, enforced after UK had returned to prewar parity, which was a signal of stability. Even though it functioned primarily as an exchange system for major currencies, with aim to stabilize international financial markets and spur economic growth, it failed to replicate the success of the classical gold standard. Research suggests that higher GDP per capita, creditor status and occurrence of hyperinflation forced countries to retain the gold standard during the interwar period. Conversely, unemployment and adherence to the sterling bloc combined with banking crises had a diverging effect. The fragility of the system was apparent, and consequently it was disavowed relatively fast, with majority of countries leaving during the 1930s. The cocktail of economic and political turmoil during the period resulted in

[21] MITCHENER, Kris James et al. Why did countries adopt the gold standard? Lessons from Japan. In *The Journal of Economic History* [online]. 2010, 70.1: 27-56.
[22] WANDSCHNEIDER, Kirsten. The stability of the interwar gold exchange standard: Did politics matter? In *The Journal of Economic History* [online]. 2008, 68.1: 151-181.

abandonment of the system and set a stage for further development of modern international monetary system.[23]

The supporters of the 'interwar' gold standard believed that it would provide stability and predictability in the monetary system, foster international trade, control exchange rate volatility, and prevent excessive inflation. Critics argued that it would lead to exacerbation of the economic crises, because of the fixed regime constraining the options for monetary policy reactions. The biggest failure attributed to the 'interwar' gold standard was that it failed to cope well with the exchange rate volatility, like its predecessor. There is evidence presented for a structural change in open economy macroeconomics between the 'classical' and 'interwar' gold standard periods. It is even suggested that the regime aggravated volatility and contributed to the occurrence of the Great Depression.[24]

However, the gold standard laid the foundations of modern international monetary system by giving states the control over money creation, which was previously conducted by commercial banks. On the other hand, since the banknotes were convertible to gold at fixed rate, it posed a potential vulnerability in the means of capital outflows, which threatened domestic gold reserves. Central banks became pivotal in the management of the supply of money and protection of their reserves to address the threats of capital outflows. International cooperation was necessary to cope with these issues, which consequently resulted into Bretton Woods System. While competition persisted, cooperation on exchange rates rose, which led states to address monetary issues without manipulating them. This period of stability stemmed not only from new financial principles but also from the flexibility offered by the fixed exchange rates.[25]

After the fall of the 'interwar' gold standard and the Great Depression, a period of economic turmoil followed, with problems consisting of beggar thy neighbor devaluations, protectionism, hot money flows and volatile exchange rates. At the height of the Second World War, the Bretton Woods system was established in 1944, to address these issues and initiate a shift towards international cooperation and consequently, globalization. Member countries agreed to fix their exchange rates to the USD, which was pegged to gold at the price of 35 USD per ounce. The main idea was that this would provide further stability and

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[23] WANDSCHNEIDER, Kirsten. The stability of the interwar gold exchange standard: Did politics matter? In *The Journal of Economic History* [online]. 2008, 68.1: 151-181.
[24] CHERNYSHOFF, Natalia et al. Stuck on gold: real exchange rate volatility and the rise and fall of the gold standard. In *National Bureau of Economic Research* [online]. 2005.
[25] KNAFO, Samuel. The gold standard and the origins of the modern international monetary system. In *Review of International Political Economy* [online]. 2006, 13.1: 78-102.

predictability in the international monetary system. The introduction of BWS aimed to promote economic reconstruction after the war, prevent competitive currency devaluations and removing trade barriers which led to the economic crises of 1930s.[26]

The system worked on three main principles: the exchange rate regime, where exchange rates were meant to fluctuate within narrow margins, but in case of fundamental disequilibrium could be adjusted; the rules for policy adjustment, which were a set of guidelines aimed at the adjustment of payment imbalances by which countries were expected to focus on a short-run internal balance through fiscal and monetary policies, while maintaining the exchange rate peg; and the reserve supply mechanism, which required the member countries to abide by the reserve constraint, while using reserves as a buffer to balance ongoing efforts to maintain internal stability with only medium-term efforts to achieve the external stability.[27]

Alongside BWS, International Monetary Fund was established, which was designed to provide financial assistance to member countries, when faced with balance of payments problems, execute surveillance over exchange rates and coordinate monetary policies. Before the system became fully operational in 1958, after the Western European members announced the convertibility of current accounts, few problems had to be resolved.

First was bilateralism. Most of the countries, except for USA, had implemented widespread exchange controls and restrictions on international trade, together with having bilateral agreements with each trading partner. The reason for this kind of measures was a shortage of international reserves in Europe and Asia because these countries struggled with producing sufficient exports in order to generate foreign exchange reserves. The second problem for the system was the universal shortage of USD. Besides the USA, which held two thirds of world's monetary gold and dollar reserves by the end of the war, the reserves of the rest of the world were exhausted. Because of high demand for essential imports and decreased export capacity, there was an ongoing current account deficit in Europe. The shortage for USD was even more amplified by the overvalued official exchange rates, however most of the countries reverted to their prewar parities, in the hope that their competitiveness was not significantly affected by the post war inflation. These problems were solved by the Marshall Plan and the European Payments Union, however the last

[26] BORDO, Michael D. The operation and demise of the Bretton Woods system; 1958 to 1971. In *National Bureau of Economic Research* [online]. 2017 Feb 27.
[27] WILLIAMSON, John. On the system in Bretton Woods. In *The American Economic Review* [online]. 1985 May 1;75(2):74-9.

problem persisted with the IMF, because it was not designed to deal with the postwar revitalization. Even though these problems were overcome consequently, the BWS effectively fell under the pressure of its own weight in between 1971 and 1973, when the USA withdrew from the system.[28]

The collapse of the BWS is attributed to several deficiencies. Gold-dollar exchange imposed a vulnerability for the USA in the means of convertibility crisis, while the adjustable peg, faced with increasing capital mobility, became a de facto fixed exchange rate system with limited capacity for effective adjustment due to high associated costs. The extensive conversion of foreign held USD into gold presented a threat to USA's gold reserves.[29]

After the collapse of the gold pool, the USA was expected to maintain price stability, because the system was basically now reliant only on the value of USD. However, the USA pursued inflationary monetary policies, which in essence decreased value of foreign exchange holdings of European countries, which started to redeem gold for dollars from USA's reserves.[30]

Also, the absence of materialization of international financial integration, despite the pegged nominal exchange rates, contributed to the consequent failure of the system. The consequence of that was the abandonment of monetary ties to gold and transition to managed floating exchange rate system, which is present to this day.[31]

1.1.2.2 Central banks' relationship with gold today

After untying the gold from the fixed exchange rate, its price started to develop freely, according to the instructions of the invisible hand over the market. However, it is without the doubt, that central banks are still interested in gold. But the question remains, why? Even though the currencies are not tied to gold in any way, except that the gold is in general traded in USD, there persist strong bound of gold and its price, with the general perception of the state of the economy, strength of the currency and general sentiment. Broadly speaking, the use of gold as an asset for the central banks, and the reason why central banks are still interested in gold, in terms of holding gold reserves, is that it is used to justify

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[28] BORDO, Michael D. The operation and demise of the Bretton Woods system; 1958 to 1971. In *National Bureau of Economic Research* [online]. 2017 Feb 27.
[29] ENGDAHL, William. What the Bretton Woods system really was designed to do. In *Executive Intelligence Review* [online]. 1997;24(33):32-5.
[30] BORDO, Michael D. The operation and demise of the Bretton Woods system; 1958 to 1971. In *National Bureau of Economic Research* [online]. 2017 Feb 27.
[31] ENGDAHL, William. What the Bretton Woods system really was designed to do. In *Executive Intelligence Review* [online]. 1997;24(33):32-5.

the trust in the fiat currency. It competes with fiat currencies and acts as a relative benchmark for it, therefore this potentially also gives the central banks the incentive to have an influence over its price. After all, during the gold standard era, the price of gold was fixed at the certain level. Furthermore, there is a lot of academic evidence that gold is perceived as safe haven asset, inflation hedge and keeper of value, therefore if something sudden and unexpected would happen to the price of gold, for sure it would bear resonating consequences in the monetary system. Therefore, it is within the best interest of the central banks to control the upside movement of the gold prices to maintain the confidence in fiat currency, and also the downside, because of the preservation of the value of their reserves. The gold lending practices of central banks, which are manifested by the gold leasing rate, create a subtle connection between central banks, bullion banks and gold mining companies, which indicates indirect and transferred management of the gold price. There are even economic justifications for central banks to manage the price of gold, especially during high inflationary periods, like in the 1970s. The empirical research suggests a potential deflection from this type of activities in 2000s, however, possibly the further development of the gold carry trade in this period offers a satisfying explanation for the price fluctuations of that time. During the period of rising gold price regime gold lending fails in its effectivity because of the rising costs of demand creation. This points to the asymmetry in terms of gold price influencing, whereas empirical research suggests, that central banks can control directly and indirectly the downward movement of the gold price, but not the move upwards. Additionally, the central bank gold agreements imply the coordination of interventions in the gold market.[32]

The Central Bank Gold Agreements started in order to address the goal of limiting the collective amount of gold, which participating parties can sell in any one year, among major European central banks in 1999, when first CBGA was signed. Given the fact that central banks own a substantial amount of mined gold, they have considerable power to influence gold's price on the market. The purpose of CBGAs was to provide stability to the gold market, which was absent from the period before these went into effect. Furthermore, the agreements provided transparency, which was beneficial for all market participants, especially for heavily indebted poor countries, which were affected most by the uncoordinated voluminous sales of gold. After twenty years of four CBGAs, in 2019, the

[32] BAUR, Dirk G. Central banks and gold. In *FIRN Research Paper* [online]. 2016 Nov 8.

ECB did not prolong the continuation of the agreements, since they fulfilled their potential, and central banks became net buyers of gold.[33]

Another possible explanation for why central banks use gold in their reserves might be offered through the perspective of the reserve portfolios' diversification. Predominantly, the central bank's reserves are financed by domestic currency liabilities, however, interest rates on these liabilities have tendency to be higher than those generated from the central banks' foreign currency assets. This frequently leads to losses from holding foreign exchange reserves that yield low returns in their books. To compensate for the losses and to reduce the exchange rate and market risks, diversification of the portfolios offered an obvious solution, and additionally was compliant with governance frameworks and enhancement of their reserve management policies. Besides US Treasury securities, agency securities, certificate of deposits, commercial papers, sovereign debt, SDRs, sovereign wealth funds, also gold, as it does not bear any credit risk, is considered a suitable option as well. This proved to be particularly useful asset during the aftermath of Global Financial Crisis in 2008.[34]

During the first decade of this millennia, there was a trend, particularly for central banks of the advanced economies, to decrease their gold reserve holdings. On the other side, the increasing central banks' reserves of emerging and recently industrialized countries seem to be the main culprits behind the gold price fluctuations of that time. The possible explanation for this behavior is that these countries require larger monetary reserves as a foundation for issuing currency, and gold is well suited for this role. In order to maintain the balance and proportion of gold within the monetary reserve portfolio, naturally, the demand for gold is stimulated.[35]

Different factor which might influence the demand for gold by central banks is global risk perception. In fact, empirical research shows that gold is perceived as a hedge by central banks, whereas the central banks modify their reserves according to the perceived global risk vulnerabilities. The magnitude of the changes depends on the specific characteristics of each individual country, in terms of "capital account openness, reserve adequacy, income status

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[33] WORLD GOLD COUNCIL. 2024. *Central Bank Gold Agreements* [online]. WGC, 2019. [cited 2024-04-28]. Available on the internet: https://www.gold.org/official-institutions/central-bank-gold-agreement

[34] GHOSH, Amit. What drives gold demand in central bank's foreign exchange reserve portfolio? In *Finance Research Letters* [online]. 2016 May 1;17:146-50.

[35] CHEN, Ku-Hsieh et al. Who upholds the surging gold price? The role of the central bank worldwide. In *Applied Economics* [online]. 2014 Aug 3;46(22):2557-75.

and currency regimes". There is also evidence, that countries with higher income have relatively higher sensitivity for the perceived risk, in comparison to developing nations.[36]

Besides geopolitical risk, other determinants influence the central banks' gold reserve holdings. Interestingly enough, the utilization of gold as an inflation and USD hedge in central banks' reserve portfolios is no different from such a use in the portfolios of individual investors or hedge funds. Monetary policy instability as well as higher exchange rate risks are also important determinants of their holdings, especially during the periods of economic turmoil, like GFC was. On the contrary, the evidence suggests that higher economic growth and financial development tends to reduce the share of gold in the reserves.[37]

Another study sheds some light on this topic from a different perspective. The research implies that the volume of gold holdings is tied with the status of 'global power'. China's and India's gold reserves increased synchronously with their economic growth, which can be further understood to the extent previous studies mentioned, i.e. the gold reserves reflect economic might and are needed to stimulate the reputation of domestic currency. The trend for China, India and Russia is set for continuation in building the gold reserves also towards the future. For the Eurozone countries, their gold reserves are a consequence of their historical position, and they are not altering the reserves according to the changing economic needs. There is also a notion for the tendency of central banks to synchronize their reduction of gold reserves positions, which is in conclusion with findings of different study mentioned above. Central banks also report their international reserves holdings without mentioning the gold positions, which might be inferred as a solution to keep sizable reserves and in case of gold depreciation on the market, to reduce the potential criticism which might materialize.[38]

For the lack of transparency, there is a reasonable explanation offered by the fact, that disclosure of intended changes to gold reserves or gold lending activities by central banks would yield signal to the broad market, rendering these changes more expensive or exacerbating volatility and uncertainty in the gold market. Instances such as central bank announcements of planned gold sales before the initial CBGA in 1999, and the subsequent

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[36] GOPALAKRISHNAN, Balogapal and Sanket MOHAPATRA. Global risk and demand for gold by central banks. In *Applied Economics Letters* [online]. 2018 Jul 12;25(12):835-9.
[37] GHOSH, Amit. What drives gold demand in central bank's foreign exchange reserve portfolio? In *Finance Research Letters* [online]. 2016 May 1;17:146-50.
[38] AIZENMAN, Joshua and INOUE Kenta. Central banks and gold puzzles. In *Journal of the Japanese and International Economies* [online]. 2013 Jun 1;28:69-90.

revelation of a gold swap by the Bank for International Settlements in 2010, underscore the impact of such disclosures.[39]

The most recent study of central banks' behavior regarding gold, conducted on wide sample of countries in 2023, shows that gold reserves are managed according to relative costs and returns, in a sense that when the expected return on financial assets such as US Treasury securities is low, compared to gold, the gold reserves tend to be expanded. The research further finds that the gold is in fact perceived as a hedge against economic and geopolitical uncertainties. The reserves managers in emerging economies tend to increase the share of gold reserves according to the perceived risk of financial sanctions, since many of the upticks in individual central banks' gold holdings are observed during the periods when they are, or they have reason to believe that they are going to be, subject to financial sanctions from USA, UK, EU and Japan. As for future expansion of gold reserves held by central banks, it remains uncertain whether they will further increase their gold reserves given recent geopolitical events and trends.[40]

1.1.3 Investment function

Besides industrial and monetary functionality of gold, there is widely utilized investment function of the precious metal. Under the investment function of gold, according to the data provided by WGC, we can understand that it consists of gold being used for bars, official coins, medals, and limited coins respectively, ETFs and other products, and we included also the category of OTC and other. The data for the year 2023 informs that roughly 28 % of the whole demand for gold that year was for investment purposes. Compared to the data from the last 14 years, it is below average of 33 % of the total demand for gold. However, serious uptick in the demand is recognized during the year 2020, when COVID crisis began to unfold, up to 60 % of demand for gold was for investment purposes, mainly the ETFs and OTC were responsible for such a jump. Among other things, in this subchapter we dive into the search for possible explanations of this phenomenon.[41]

In order to understand the role of gold in the investment sphere, an important distinction has to be made; what is a hedge, what is a diversifier, and what is a safe haven.

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[39] BAUR, Dirk G. Central banks and gold. In *FIRN Research Paper* [online]. 2016 Nov 8.
[40] ARSLANALP, Serkan et al. Gold as international reserves: A barbarous relic no more? In *Journal of International Economics* [online]. 2023 Nov 1; 145:103822.
[41] WORLD GOLD COUNCIL. 2024. *Historical demand and supply* [online]. WGC, 2024. [cited 2024-03-05]. Available on the internet: https://www.gold.org/goldhub/data/gold-demand-by-country

"*A hedge is defined as an asset that is uncorrelated or negatively correlated with another asset or portfolio on average.*" However, hedging does not necessarily guarantee to reduce the losses during the stressing and tumultuous market periods as the asset being hedged against could demonstrate a positive correlation during such times and a negative correlation during normal market conditions, resulting in an average negative correlation overall. "*A diversifier is defined as an asset that is positively (but not perfectly correlated) with another asset or portfolio on average.*" Similarly to the hedge, the correlation property is expected to hold on average, and might diverge during the specific market periods. "*A safe haven is defined as an asset that is uncorrelated or negatively correlated with another asset or portfolio in times of market stress or turmoil.*" The ability to exhibit a nonpositive correlation during the stressful and turbulent periods with the broad portfolio is what makes safe haven assets desired, especially if the correlation is negative during such a period. Yet, during normal or bullish market conditions, the correlation can be either positive or negative. The research provides evidence that for US, UK and Germany, gold acts as a hedge on average and safe haven asset in extreme market conditions for stocks, however this is not true for bonds. Also, it is false to imagine gold being a safe haven for the whole duration of the crisis, its role is more like a buffer, a flight to quality, during the worst periods and acts as a safe haven asset for approximately 15 trading days, i.e. 3 weeks, after that period, the gold price tends to go down.[42]

Baur's and McDermott's study from 2010 performed on data between the years 1979 and 2009 looked at 53 countries, and found complementary results, but with certain nuances. In the developed markets, gold is purchased as a reactionary measure for a severe market downturn. The types of investors' reaction in developed and emerging markets differ. In developed markets, the gold acquisition is typically used for the flight to safety. In emerging markets, investors prefer to move their investments from emerging markets towards developed market stocks, instead of seeking out the alternative safe haven assets. Gold acts as a hedge and safe haven for major Eurozone markets and Switzerland, UK, and USA, but not for Australia, Canada, Japan, or emerging markets like BRIC countries.[43]

Even though gold and bonds are both considered safe haven assets, they are major contenders in this realm and differ quite substantially. Bonds' qualities are stability, low

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[42] BAUR, Dirk G. and Brian M. LUCEY. Is gold a hedge or a safe haven? An analysis of stocks, bonds and gold. In *Financial review* [online]. 2010 May;45(2):217-29.
[43] BAUR, Dirk G. and Thomas K. MCDERMOTT. Is gold a safe haven? International evidence. In *Journal of Banking & Finance* [online]. 2010 Aug 1;34(8):1886-98.

volatility, and liquidity, with predictable returns and tighter bid-ask spreads compared to gold. However, gold offers naturally a protection against inflation, currency and default risks, and its supply is not controlled by any single entity. The particular evidence from this research of Baur and McDermott from 2013 suggests that gold seems to be stronger safe haven than bonds, with greater positive response to shocks. This may be partially due to behavioral reasons, because of the potential perception of gold being the ideal choice for the "worst case scenario". Gold's tangible nature and independence from single entities decisions contribute to its attractiveness during chaotic times.[44] However, more recent research from 2017 done by Shahzad et al. found different results. During normal and bullish market states, gold indeed exhibit hedging and safe haven qualities in relationship to stocks, however when both markets are under significant stress, gold tends to comove with stocks, which erases its hedging and safe haven abilities. This might be the result of the expansion of the financialization of the commodity markets, widening its investor base. Bonds exhibit negative relationship with stocks when both markets experience turmoil. Nevertheless, it is important to note that the safe haven phenomenon for both types of assets is short lived, however bonds perform better than gold in extreme market stress periods. Additionally, the relationship triangle is market state and country specific.[45] The distinct qualities of gold and bonds as safe haven are further confirmed by another research, where the characteristics of each of those two are further expressed. More specifically, this research implies that 10-year Treasury bond is more stable than gold in terms of volatility, but produces lower returns, while gold, especially during high volatility regimes can offer higher returns.[46]

The evidence implies that gold can be hedge against depreciating dollar, but not entirely against inflation. The simple explanation for the USD hedge might be offered by the fact that gold is denominated in this currency, so if the dollar depreciates, the nominal value of gold tends to rise in order to preserve its real price. This underlines the fact that gold indeed still fulfills the role of mitigating the exchange rate risks and is viable for this role not only for central banks, but also for investors.[47] Evidence from a panel data analysis conducted on the 18 major gold producing, gold consuming and key currency countries of

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[44] BAUR, Dirk G. and Thomas K. MCDERMOTT. Financial turmoil and safe haven assets. Available at *SSRN 2004796* [online]. 2013 May 13.
[45] SHAHZAD, Syed Jawad Hussain et al. Dependence of stock markets with gold and bonds under bullish and bearish market states. In *Resources Policy* [online]. 2017 Jun 1;52:308-19.
[46] FLAVIN, Thomas J. et al. Identifying safe haven assets for equity investors through an analysis of the stability of shock transmission. In *Journal of international financial markets, institutions and money* [online]. 2014 Nov 1;33:137-54.
[47] BAUR, Dirk G. Explanatory mining for gold: Contrasting evidence from simple and multiple regressions. In *Resources Policy* [online]. 2011 Sep 1;36(3):265-75.

the world, on a data between the years of 1999 and 2015, yields results that gold can effectively hedge exchange rate risk, when dealing with currency depreciation, but only in the short term, and the effect is stronger particularly for gold producing countries.[48] For inflation, it is a different case. The inflation adjusted gold's price reached all time high during the 1980s and remained unsubdued ever since, therefore by this logic gold is not an effective inflation hedge in the USD environment, although it might mitigate it to some extent.[49] Nonetheless, if we look at the longer time perspective, we might find gold's inflation hedge properties to hold, but it is questionable, whether the period in question is within the investment horizon of investors.[50] Further research suggests that the relationship between gold and inflation is not simply black and white. The interconnectedness of the two depends on the particularities of inferred markets and also on different states of the market. Evidence suggests that gold in fact might act as a hedge against inflation, but only during normal market conditions. During bear markets it is more advisable to utilize gold for its safe haven property, rather than for inflation hedging.[51]

The findings from research into interconnection between USD and gold in emerging markets conclude that both of these assets fulfil the role of hedge and safe haven assets, however the USD is considered to be superior to gold, when hedging risk of emerging markets indices during critical market periods.[52]

In regard to its important peer from commodity category, gold together with other precious metals surprisingly does not provide an effective safe haven effect for decreasing crude oil prices.[53]

Number of researchers also explored the possibility, if gold could be replaced in its ability in being a traditional safe haven asset by Bitcoin. Bitcoin can be potentially perceived as an asset allocated between traditional currency, such as USD, and an asset, such as gold. BTC acts as a medium of exchange and its response towards federal funds rate imitates the response of a currency. Due to its decentralized nature and lack of regulation, Bitcoin will

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[48] WANG, Kuan-Min and Yuan-Ming LEE. Hedging exchange rate risk in the gold market: A panel data analysis. In *Journal of Multinational Financial Management* [online]. 2016, 35: 1-23.
[49] BAUR, Dirk G. Explanatory mining for gold: Contrasting evidence from simple and multiple regressions. In *Resources Policy* [online]. 2011 Sep 1;36(3):265-75.
[50] ERB, Claude B. and Campbell R. HARVEY. The golden dilemma. In *Financial Analysts Journal* [online]. 2013, 69.4: 10-42.
[51] SHAHZAD, Syed Jawad Hussain, et al. Does gold act as a hedge against different nuances of inflation? Evidence from Quantile-on-Quantile and causality-in-quantiles approaches. In *Resources Policy* [online]. 2019, 62: 602-615.
[52] WEN, Xiaoqian and Hua CHENG. Which is the safe haven for emerging stock markets, gold or the US dollar? In *Emerging Markets Review* [online]. 2018 Jun 1;35:69-90.
[53] CHEEMA, Muhammad A. et al. Are there any safe haven assets against oil price falls? In *Applied Economics* [online]. 2023, 1-16.

never behave exactly like traditional currencies in the market. It resembles gold in its hedging characteristics and symmetric reaction to the market news. Additionally, BTC's reaction is faster than gold's, because of the faster trading regime.[54] As a contestant towards gold, research of Bouri et al. from 2020 implies that BTC surpasses gold in safe haven functionality against stocks and USD, which might be partially because of incompatible nature of BTC, perceived as an element isolated from other financial assets.[55] However, literature is not consistent with BTC being supreme to gold, e.g. Jin et al. in their work from 2019 suggest that gold market outperforms both BTC and crude oil market in assimilating new information, thereby offering more insight into explaining the price movements and variance within the hedging assets system.[56]

It is crucial to note that our standard perception of gold as a safe haven asset stem mainly from the above-mentioned research, where there was performed an analysis of gold after GFC, but before COVID crisis. However, the influence of COVID crisis on the market dynamics might have challenged gold's qualities in terms of being a hedge or a safe haven. From the beginning of the crisis thanks to research performed by Ji et al. in 2020, we obtain evidence that gold together with soybean futures could be used as a safe haven asset during the COVID crisis. This research was performed on the data from between December 2019 and March 2020.[57] Akhtaruzzaman et al. in their study from 2021 portray a different picture. By using Baur's and McDermott's and Baur's and Lucey's approaches, they partially confirm the findings of Ji et al. on the data span between December 2019 and March 2020, where they find that gold indeed served as a safe haven for stock markets, but the sample data from March 2020 to April 2020 provide a twist. During the latter period, gold has lost its safe haven property for stock indices, potentially because of extensive intervention by governments in the form of fiscal and monetary stimuli. That lead to growth of correlations between gold and other assets, which in turn increased the hedging costs to the point that gold also lost its attractiveness for this purpose. They inferred that gold fulfils the purpose

[54] DYHRBERG, Anne Haubo. Bitcoin, gold and the dollar–A GARCH volatility analysis. In *Finance research letters* [online]. 2016, 16: 85-92.
[55] BOURI, Elie, et al. Bitcoin, gold, and commodities as safe havens for stocks: New insight through wavelet analysis. In *The Quarterly Review of Economics and Finance* [online]. 2020, 77: 156-164.
[56] JIN, Jingyu, et al. Which one is more informative in determining price movements of hedging assets? Evidence from Bitcoin, gold and crude oil markets. In *Physica A: Statistical Mechanics and its Applications* [online]. 2019, 527: 121121.
[57] JI, Qiang et al. Searching for safe-haven assets during the COVID-19 pandemic. In *International Review of Financial Analysis* [online]. 2020, 71: 101526.

of safe haven during the earlier stages of the crisis.[58] Another study, done by Chemkha et al. in 2021 provides evidence, that gold to a low extent preserved its safe haven abilities, however became 'weak' safe haven. BTC has shown better results in terms of returns when compared to gold, which might be attributed to the fact that it is not dependent on standard assets, although its volatility is not suitable for being safe haven asset per se.[59] This notion is further confirmed by the work of Disli et al. also from the year of 2021, in which they assessed gold's, crude oil's and BTC's ability to be safe haven during the COVID crisis. They find that assets previously thought to possess 'strong' safe haven qualities, i.e. gold, might have lost this ability due to the different nature of the crisis.[60] Cheema et al. in their work from 2022 further confirm the change in gold's quality as a safe haven asset. They compared its role both during the GFC and during the COVID, and found that gold, in fact, lost its ability to provide investors with safe haven's insulation, like it used during previous crises. One explanation might be offered from a perspective of gold's price depreciation which occurred after 2011, which resulted in a loss of trust of investors. Another explanation might be that cryptocurrencies, since they are detached from traditional market settings, might offer better insulation against market downturns, or that financial derivatives might have offered the desired hedging abilities. Therefore, the character of asset being a safe haven is not static and may vary over time and different circumstances and needs to be reevaluated consistently in the light of unfolding situation.[61]

An interesting approach to measure gold's potential effect on investor's decision making and portfolio configuration is potentially offered through the lens of examination of relationships of gold and economical and geopolitical uncertainty. These factors definitely play a role in the financial markets as the research demonstrates. As the research from 2020 by Qin et al. shows, by examining the time period between 1979 and 2018 and by utilizing specific geopolitical risk index, they managed to find evidence that gold should be held during turbulent eras, when the geopolitical risk is on the rise. But the relationship is not straightforward and there were periods when gold price declined during the high geopolitical risk and increased during the low geopolitical risk, therefore the relationship is not stable

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[58] AKHTARUZZAMAN, Md, et al. Is gold a hedge or a safe-haven asset in the COVID–19 crisis?. In *Economic Modelling* [online]. 2021, 102: 105588.
[59] CHEMKHA, Rahma, et al. Hedge and safe haven properties during COVID-19: Evidence from Bitcoin and gold. In *The Quarterly Review of Economics and Finance* [online]. 2021, 82: 71-85.
[60] DISLI, Mustafa, et al. In search of safe haven assets during COVID-19 pandemic: An empirical analysis of different investor types. In *Research in International Business and Finance* [online]. 2021, 58: 101461.
[61] CHEEMA, Muhammad A. et al. The 2008 global financial crisis and COVID-19 pandemic: How safe are the safe haven assets? In *International Review of Financial Analysis* [online]. 2022, 83: 102316.

and varies. An interesting observation is made that gold price might successfully predict the geopolitical risk, when the metal's price is on the rise.[62]

Another research from the same author and his colleagues, Qin et al., provides evidence that also global economic policy uncertainty influences the price of gold. The influence is dependent on whether there is ongoing economic crisis period or not. According to the research gold was a potent hedge for risks of GEPU during the Asian financial crisis, dot-com bubble and GFC.[63] However, Wu et al. in 2019 found, that neither gold, nor BTC can be considered as a hedge against economic policy uncertainty in the US market. The evidence reveals, that in the US, the EPU can be potentially hedged by BTC or gold, but the effect is weak at best during the extreme bearish and bullish markets.[64] This is further confirmed by another research which underlines the major country dependent differences, when measuring the effects of EPU on the gold price. Not only the effects of EPU on gold's price change over time, but this finding also implies that effectiveness of gold being a safe haven depends on the country specific and economic conditions. Developing countries' EPU's exert higher volatility response of gold's prices than those of developed nations. Interestingly, from 20 countries, the Japan's EPU has the largest influence on the price of gold.[65]

1.2 Gold's price, its determinants, and their relationships

As it is with the assets on the capital markets, their price development is determined by the constantly changing universe of factors. For gold it is no different. After the collapse of BWS, gold's price started to float freely, from previously maintained fixed exchange rate of 35 USD per ounce.[66] This transition meant, that from the sole effect of control of governmental international agreement, gold's price became exposed to the various macroeconomic effects and market forces. Vast array of research has been conducted in order to understand and uncover the elemental forces behind the movement of this metal's price.

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[62] QIN, Meng et al. Should gold be stored in chaotic eras? In *Economic research-Ekonomska istraživanja* [online]. 2020;33(1):224-42.
[63] QIN, Meng et al. Should gold be held under global economic policy uncertainty? In *Journal of Business Economics and Management* [online]. 2020 Apr 20;21(3):725-42.
[64] WU, Shan et al. Does gold or Bitcoin hedge economic policy uncertainty? In *Finance Research Letters* [online]. 2019 Dec 1;31:171-8.
[65] CHAI, Gao et al. Dynamic response pattern of gold prices to economic policy uncertainty. In *Transactions of Nonferrous Metals Society of China* [online]. 2019 Dec 1;29(12):2667-76.
[66] BORDO, Michael D. The operation and demise of the Bretton Woods system; 1958 to 1971. In *National Bureau of Economic Research* [online]. 2017 Feb 27.

1.2.1 Gold's price determinants

The literature consists of numerous approaches towards the classification of gold's price determinants. Most often it is decentralized and focusing only on sole or multiple various factors, although more general approaches emerge. In the aggregate sense, one option to classify the factors, might be from the supply and demand point of view. On the demand side it is population, GDP, improvement of living standards, monetary policy, USD exchange rates, technological development and speculative or other effects. On the supply side, the determinants could be gold reserves, recycled gold, newly mined gold, technological advancements in the gold mining and extraction technology, monetary system, political and geopolitical factors and short term 'shock' factors like natural disasters or conflicts.[67] Another possible view might be from the long-term and short-term perspective. Long-term factors constitute of raw material cycle, demand, supply, or world population. Short-term factors might be the level of interest rates, seasonality, geopolitical events, media information or purchasing power of USD.[68] Since the approaches in the literature overlap, we decided to break down each of the important determinants of the gold's price.

1.2.1.1 Demand

The total demand for gold continues to increase consistently since the year of 2020, and remains quite strong. The total demand is composed from various areas of interest and utilization, but mainly from jewelry, technology, dentistry, and investment demand, e.g. in the form of gold coins and bars, or physically backed ETFs. Historically and socio-culturally, biggest demand hubs for gold jewelry are China and India, with their average demand over the last 14 years for the gold jewelry being 58 % from the world's total jewelry gold demand. From the industrial point of view, the gold's demand stems from its usage in dentistry and electronics, however the continuously rising gold's price together with technological advancements in the particular fields caused deflection in favor of more affordable alternative, e.g. copper in electronics and plastic or ceramics in dentistry. However, considerable shift occurred in 2003 for the investment demand, when first gold ETF was introduced to the market. Baur claims that this has caused a structural change, as it enabled

[67] ŠIMÁKOVÁ, Jana. Analysis of the relationship between oil and gold prices. In *Journal of finance* [online]. 2011, 51.1: 651-662.
[68] MAMCARZ, Katarzyna, et al. Long-term determinants of the price of gold. In *Studia Ekonomiczne* [online]. 2015, 252: 80-94.

wider possibilities of the participation on the gold market for smaller investors, thus influencing gold's price to some extent.[69, 70] Interesting factor which is more and more influential over the gold's price is the rise of speculation on the financial markets.[71] The issue with speculation is that it can possibly induce volatility in the gold futures markets and diverge the price of the metal away from its fundamental value.[72]

1.2.1.2 Supply

The WGC estimates that total above ground supply is around 212,582.46 tons, up to the end of the year 2023, from which 45.4 % constitutes the jewelry, 17.3 % is held by the central banks worldwide, 22.3 % is allocated in a private investment and the rest of 15 % is categorized as other. Interestingly enough, from the investment supply, the vast majority of gold is held in bars and coins, constituting of 93.2 %, while the remaining 6.8 % is used to physically back ETFs.[73] New gold's supply is relatively small to its existing stock, averaging at 2.5 % annual increase to its total stock over the last 14 years.[74] This is the main difference between gold and other storable commodities, for example, when compared to copper, gold does have enormous stock relative to its yearly inflow. New gold enters the market from two primary sources, predominantly from mining and recycling, although to a certain extent it is supplied also by net producer hedging, central banks' and ETF's sales.[75] According to WGC, the current biggest world's mines producers are China, Russian Federation, Australia, Canada and USA.[76] The gold scrap supply is composed from recycling jewelry and electronics, whereas certain amount of gold is lost permanently on an annual basis due to its presence in the electronics in such a miniscule volume, that it is not profitable to retrieve it. Evidence suggests certain amount of correlation between economic crises and spikes in gold's scrap supply. In the past, mainly from the 1980s, central banks were net sellers of

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[69] O'CONNOR, Fergal A., et al. The financial economics of gold—A survey. In *International Review of Financial Analysis* [online]. 2015, 41: 186-205.
[70] WORLD GOLD COUNCIL. 2024. *Historical demand and supply* [online]. WGC, 2024. [cited 2024-03-28]. Available on the internet: https://www.gold.org/goldhub/data/gold-demand-by-country
[71] ERDOĞDU, Aylin. The most significant factors influencing the price of gold: An empirical analysis of the US market. In *Economics World* [online]. 2017, 5.5: 399-406.
[72] WANG, Hao et al. Influence factors of international gold futures price volatility. In *Transactions of Nonferrous Metals Society of China* [online]. 2019, 29.11: 2447-2454.
[73] WORLD GOLD COUNCIL. 2024. *Above-ground stock* [online]. WGC, 2024. [cited 2024-03-30]. Available on the internet: https://www.gold.org/goldhub/data/how-much-gold
[74] WORLD GOLD COUNCIL. 2024. *Historical demand and supply* [online]. WGC, 2024. [cited 2024-03-28]. Available on the internet: https://www.gold.org/goldhub/data/gold-demand-by-country
[75] O'CONNOR, Fergal A., et al. The financial economics of gold—A survey. In *International Review of Financial Analysis* [online]. 2015, 41: 186-205.
[76] WORLD GOLD COUNCIL. 2024. *Global mine production* [online]. WGC, 2023. [cited 2024-03-28]. Available on the internet: https://www.gold.org/goldhub/data/gold-production-by-country

gold, therefore providers of supply, however the course changed after the aftermath of GFC, when in 2010, the central banks became net gold buyers once again. Producer hedging involves supplying the market through forward sales and leasing arrangements. Forward sales do not provide liquidity to the spot market, because they are restricted by the duration of the contract, but it yields liquidity to the derivatives market and enables producers to secure current prices for the anticipated future mine output. On the other hand, gold leasing injects liquidity directly to the spot market and provides instant funding to miners' operations. For gold miners it is also more viable alternative as financing through USD loans, because usually gold lease rates are lower.[77]

1.2.1.3 Macroeconomic variables

Several studies researched the impact of various macroeconomic factors on the gold's price. In general, it makes perfect sense, given the fact of vast gold utilization and firm position in our world and economics. And indeed, the evidence further confirms, that macroeconomic variables play significant role in influencing the gold's price. Research by Fang et al. performed within US futures markets by utilizing GARCH-MIDAS approach yielded results confirming that macroeconomic factors are determinants contributing to the long-term volatility in this particular market. They examined the influence of ten macroeconomic variables, starting with inflation rate, new consumer goods and material orders, capacity utilization, employment growth, diffusion index, economic policy uncertainty, consumer confidence, industrial production growth, housing and M1 growth. Their findings imply strong influence of these factors on the gold market volatility, particularly during the economically tumultuous periods. Particularly, inflation, capacity, employment and EPU exhibit positive influence on the volatility of the gold market, while diffusion index, orders and confidence indices yield a negative influence. Interestingly, they conclude, that addition of lower frequency macroeconomic variable data improves the forecasting ability of the model.[78] By the utilization of real time forecasting approach, Pierdzioch et al. were able to quantify the predictive power of international business cycle on gold's prices. Their results are however only adequate for US based investors but shed light on the particularities of output gaps influence on gold price, inferred from G7 countries'

[77] O'CONNOR, Fergal A., et al. The financial economics of gold—A survey. In *International Review of Financial Analysis* [online]. 2015, 41: 186-205.
[78] FANG, Libing et al. Forecasting gold futures market volatility using macroeconomic variables in the United States. In *Economic Modelling* [online]. 2018, 72: 249-259.

industrial production.[79] A reverse surface response factor methodology research conducted by Qian et al. provides further evidence of the aggregate interconnectedness of the broad spectrum of macroeconomic variables, not only in the sense of certain economic metrics, but also other major influencers, such as USD, FED funds rates, exchange rates, oil prices, and S&P500. Among other things, CPI had demonstrably significant impact on gold prices.[80] Besides other variables, there also exists evidence that the US economy and whole dollar based monetary system are drivers of gold's prices.[81]

1.2.1.4 Inflation and interest rates

Even though inflation as a regularly measured macroeconomic quantity belongs to the macroeconomic variables category, it is extensively and thoroughly researched determinant, since long lastly assumed gold's relationship with it. Levin et al. claim long-term relationship between gold's price and general price in the USA. Moreover, their long-term relationship comoves in such a way that it lays a statistically significant basis for one-to-one correspondence between both variables' movement. Short-term relationships between gold prices and inflation, inflation volatility and credit risk have been found also statistically significant in a positive sense, while the influence of USD trade weighted exchange rate and gold lease rate exhibited negative response in the price of gold. When compared to world's inflation and its volatility, no significant relationship could be claimed based upon the results from the research, therefore rendering the relationship plausible only within the US environment.[82] Additionally, this premise is further confirmed by the fact that gold's price in the 1830s and in 2005 was basically the same, in real terms, inflation adjusted. Even though it might be tempting to simply assess that gold's price merely follow the current rate of price level increase, it is not the case. Instead, it often undergoes extended periods where its movement appears disconnected from inflationary patterns.[83] Baur also provides evidence aligned with the narrative that gold is being substantially affected by the changes in the price level, interest rates, currency changes and central bank reserve policies, among others. His research provides evidence that inflation belonged between prime determinants

[79] PIERDZIOCH, Christian et al. The international business cycle and gold-price fluctuations. In *The Quarterly Review of Economics and Finance* [online]. 2014, 54.2: 292-305.
[80] QIAN, Yao et al. The analysis of factors affecting global gold price. In *Resources Policy* [online]. 2019, 64: 101478.
[81] DEY, Shubhasis. Historical Events and the Gold Price. In *Indian Institute of Management* [online]. 2016, 1-27.
[82] LEVIN, Eric J.; MONTAGNOLI, A.; WRIGHT, R. E. Short-run and long-run determinants of the price of gold. In *World Gold Council* [online]. 2006.
[83] ECONOMICS, Oxford. The impact of inflation and deflation on the case for gold. Commissioned by World Gold Council, 2011.

of gold's price in the 1970s, but not in the following period of the so-called "great moderation", during the 1980s and 1990s, but consequently reemerged between the years of 2003 and 2013.[84] Batten et al. utilized ARDL model in their research and it yielded generally contradictory results. They infer, that if the period of the early 1980s is excluded from the dataset, which spans from 1985 until 2012, no cointegration between gold and inflation exists. They conclude that no consistent relationship between these two variables is present.[85] Zhu et al. by employing linear regression in combination with GARCH model further confirm the notion that gold's inflation hedge properties are not static, whereas their research yielded results confirming that it has lost this ability after May 1997 in the UK and after 2003 in the USA.[86]

Interest rates are directly connected to the inflation, and therefore also to the gold, as its potential determinant. An increase in the real interest rates cause the rise of the opportunity cost of holding gold, because gold does not yield any interest and replacing it with bonds is more viable option. Therefore, periods of negative real interest rates ought to provide nurturing environment for the gold's price, and indeed, this was the case during the 1970s, and conversely the following hawkish development in the spirit of significant rate hikes in the 1980s might have influenced gold's price plunge, also among other factors accounted for.[87] Baur's findings from 2013 are also consistent with the notion of interest rates are influencing the price of gold, particularly low or negative ones.[88]

1.2.1.5 Monetary policy

Besides inflation, in 2018 Zhu et al. investigated the impact of monetary policy on the gold's prices, more specifically, quantitative easing announcements of four world's dominant central banks, i.e. US Federal Reserve, European Central Bank, Bank of England, and Bank of Japan. The results provide evidence that FED's QE announcements had in fact significant impact on the gold's price, because out of twelve announcements, eight of them resulted in notable gold's price response on the next day. Statements in favor of QE resulted in positive upticks, while proclamation of the reduction of spending were followed by gold's

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[84] BAUR, Dirk G. Gold-Fundamental drivers and asset allocation. In *SSRN* [online]. 2013.
[85] BATTEN, Jonathan A. et al. On the economic determinants of the gold–inflation relation. In *Resources Policy* [online]. 2014, 41: 101-108.
[86] ZHU, Yanhui et al. The impact of monetary policy on gold price dynamics. In *Research in International Business and Finance* [online]. 2018, 44: 319-331.
[87] ECONOMICS, Oxford. The impact of inflation and deflation on the case for gold. Commissioned by World Gold Council, 2011.
[88] BAUR, Dirk G. Gold-Fundamental drivers and asset allocation. In *SSRN* [online]. 2013.

declines in price. ECB had weaker, but still recognizable impact, whereas three out of eight QE announcements were followed by the anticipated movement in gold's price. For the case of BoE and BoJ, there is evidence that their announcements do not influence the gold in a way that the applied methodology would recognize.[89] Anzuini et al. employed VAR model in 2012 to infer whether monetary policy does have implications on the commodity prices, and their findings are basically in conjunction with the previously mentioned findings, however there are slight differences. They conclude that the expansionary monetary policy of the US does have an effect on commodity prices, although this effect is not of great magnitude. They forecasted that the monetary policy easing would have subtle positive impact on commodity prices.[90] The fact that 17.3 % of all above ground stocks of gold are held by central banks cannot be underestimated when examining the determinants of the gold's price.[91] Consequently, monetary policy, mostly executed by central banks, had always had recognizable impact on gold prices, while there were consequential shifts in trends of relationship of central banks to gold over the history. After the establishment of BWS, central banks became net buyers of gold in order to build up their gold reserves. During the 1970s and 1980s the trend flattened and consequently in the 1990s the central banks became net sellers of the asset. This had an obvious impact on gold prices and reversed in the early 2000s. After GFC, central banks became net buyers of gold again and this trend continues to this day.[92] Baur's research also confirmed that central banks activities influence the gold.[93]

1.2.1.6 Uncertainty

A prevalent factor of influence on the capital and financial markets is uncertainty. Without having a crystal ball, it is particularly hard to estimate what is going to happen in the future, although, based on the vast amount of literature examining the gold's relationship with uncertainty as such, we might have some insights into how this difficultly quantifiable variable might affect the metal's price.

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[89] ZHU, Yanhui et al. The impact of monetary policy on gold price dynamics. In *Research in International Business and Finance* [online]. 2018, 44: 319-331.
[90] ANZUINI, Alessio et al. The impact of monetary policy shocks on commodity prices. In *Bank of Italy Temi di Discussione Working Paper* [online]. 2012, 851.
[91] WORLD GOLD COUNCIL. 2024. *Above-ground stock* [online]. WGC, 2024. [cited 2024-03-30]. Available on the internet: https://www.gold.org/goldhub/data/how-much-gold
[92] ECONOMICS, Oxford. The impact of inflation and deflation on the case for gold. Commissioned by World Gold Council, 2011.
[93] BAUR, Dirk G. Gold-Fundamental drivers and asset allocation. In *SSRN* [online]. 2013.

Bilgin et al. in 2018 took an aggregate approach and examined the four major uncertainty measures, that is volatility in terms of VIX, skewness, the global economic policy uncertainty, and the partisan conflict indices by employing nonlinear ARDL model. Over the span of 20 years, between January 1997 and May 2017, among other findings, they provide evidence, that negative changes in VIX induce positive gold's response and symmetrical response to change in GEPU.[94] A nonlinear Interacted-VAR model was in 2023 used by Chen et al., in order to research gold's prices behavior in response to economic uncertainty during specific, zero lower bound regime. Their findings provide evidence that the uncertainty shocks affect gold more intensively during the ZLB periods, with the gold's volatility being more prevalent in this regime throughout times of increased economic uncertainty. This underlines the notion, that during more volatile periods, gold might be still considered as a refuge.[95]

On the matter of US partisan conflict, more in-depth approach is performed by Qin et al. in 2020, where they perform Granger causality tests in their research and find evidence, that causal relationship is present between gold's price and PC on a handful of occasions. PC exhibits positive effect on gold's prices, which is interpreted as a risk-hedge function of gold, while lower PC results in decrement of gold prices. The relationship works in both ways, as gold's price exhibits negative effects on PC.[96] In the year of 2020 Jiang et al. examines the PC in broader perspective, by looking at the interactions of prices of strategic commodities with PC index. Their research yields compelling evidence in favor of the notion that US PC index exhibits notable predictive effect on oil and gold returns, particularly at the tails of their conditional distributions. However, the oil's and gold's returns are observed to react distinctively to PC across varying market conditions. For gold, the PC's predictive power is of importance when it is experiencing bullish market conditions, although the volatility of gold is affected by PC index across whole conditional distribution.[97]

Various uncertainty measures were subject to research by Balcilar et al. from 2016, which was performed by nonparametric causality-in-quantiles test. Their findings underscore the importance of frequency of the data being examined, as the lower frequency

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[94] BILGIN, Mehmet Huseyin, et al. The effects of uncertainty measures on the price of gold. In *International Review of Financial Analysis* [online]. 2018, 58: 1-7.
[95] CHEN, Peng et al. Do gold prices respond more to uncertainty shocks at the zero lower bound?. In *Resources Policy* [online]. 2023, 86: 104057.
[96] QIN, Meng, et al. Is factionalism a push for gold price?. In *Resources Policy* [online]. 2020, 67: 101679.
[97] JIANG, Yong, et al. Does the price of strategic commodities respond to US partisan conflict?. In *Resources Policy* [online]. 2020, 66: 101617.

data provides less statistically significant evidence. The interesting finding is that measures of economic and political uncertainty do not surely exert a more significant impact on the tails of the conditional distribution of gold price movements compared to the center of the distribution. Contrarily, their analysis provides evidence that most significant causal effects take place at the center of the gold's price distribution. That means that stronger effects of uncertainty influence gold's returns and volatility during relatively calm periods, rather than during market turmoil. However, their finding does not mean that singular, higher magnitude effects like economic crises or geopolitical events do not affect gold prices, moreover, it underlines the importance of inspecting the whole conditional distribution of the gold's price.[98] These results are more or less in line with the newer evidence from 2018 provided by Raza et al., who performed the research based on the same methodology, but on a wider spectrum of countries, and found supporting evidence that gold's prices are indeed caused by the EPU in eight different countries, but divergently, they infer that the causality is predominant at the lower tails of the distribution.[99] A combination of the wavelet decomposition and the copula approach is employed by Beckmann et al. in their work from 2019, in order to infer into the uncertainty's and gold's relationship. EPU is confirmed to be positively related to the gold' price changes, macroeconomic and inflation uncertainty exhibit negative relationship towards gold's price behavior. The possible explanation is offered by the fact that when the uncertainty is more often mentioned in the newspapers the demand for gold increases. Conversely, the rise of unpredictable aspects of macroeconomic indicators are aligned with the negative gold's returns. This provides evidence that gold fails to hedge unpredictability in the financial markets and economy.[100]

The geopolitical risk also plays an important role in influencing gold returns, for which Gozgor et al. in their work from 2019, provides evidence by applying Bayesian Graphical Structural VAR model, alongside with US Real Effective Exchange Rate. They conclude also that gold's second moment is heavily dependent on its past values.[101] More comprehensive approach done by Li et al. examines information spillovers in different time and frequency domains between gold, oil, and BRICS geopolitical risks. Besides noticing

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[98] BALCILAR, Mehmet et al. Does uncertainty move the gold price? New evidence from a nonparametric causality-in-quantiles test. In *Resources Policy* [online]. 2016, 49: 74-80.
[99] RAZA, Syed Ali et al. Does economic policy uncertainty influence gold prices? Evidence from a nonparametric causality-in-quantiles approach. In *Resources Policy* [online]. 2018, 57: 61-68.
[100] BECKMANN, Joscha et al. Gold price dynamics and the role of uncertainty. In *Quantitative Finance* [online]. 2019, 19.4: 663-681.
[101] GOZGOR, Giray, et al. The role of uncertainty measures on the returns of gold. In *Economics Letters* [online]. 2019, 185: 108680.

stronger short-term volatility spillovers between oil and gold market, they conclude that China's geopolitical risks have the largest impact on gold's prices from among other countries, meanwhile gold is also affecting China's geopolitical risks.[102]

The issue specific approach was conducted by Atri et al. in 2021 by employing ARDL model, in order to quantify the influence of COVID-related news on the price of gold. They provide evidence, that gold is less susceptible to negative COVID-related news in comparison to crude oil, whereas media coverage of the numbers of infections and deaths positively impact gold's price.[103] During the COVID crisis, gold together with palladium experienced a price bubble, with gold being an asset experiencing multiple bubble episodes throughout the crisis, which furthermore emphasize the effects of uncertainty over the asset's price.[104]

1.2.1.7 Oil

Oil belongs amongst world's most important and traded commodities and its relationship with gold is often times a subject to scientific inquiry. Le and Chang inspected in 2012 the influence of oil's behavior upon gold's price. By employing structural VAR model approach on data spanning from May 1994 to April 2011, they were able to identify statistically significant influence of oil price shocks on gold. The evidence suggests that the influence is of symmetrical and nonlinear character, therefore excluding the existence of stable, linear, and long-term relationship among the commodities. Furthermore, the oil price shocks start influencing gold within one month after the event and fade out over the following months.[105] Shahbaz et al. later in 2017 confirm the nonlinearity of the relationship between the assets, by employing nonparametric causality-in-quantiles approach and additionally provide evidence of frail predictive ability of oil prices towards gold. Similarly, like among other studies utilizing this particular approach, also this research provides corroboration of the most significant effect of a particular variable, in this case oil, affecting gold's prices, that it takes place at the times of relatively normal gold's price fluctuations,

[102] LI, Yingli, et al. Analyzing the time-frequency connectedness among oil, gold prices and BRICS geopolitical risks. In *Resources Policy* [online]. 2021, 73: 102134.
[103] ATRI, Hanen et al. The impact of COVID-19 news, panic and media coverage on the oil and gold prices: An ARDL approach. In *Resources Policy* [online]. 2021, 72: 102061.
[104] MAGHYEREH, Aktham and Hussein ABDOH. Can news-based economic sentiment predict bubbles in precious metal markets?. In *Financial Innovation* [online]. 2022, 8.1: 35.
[105] LE, Thai-Ha and Youngho CHANG. Oil price shocks and gold returns. In *International Economics* [online]. 2012, 131: 71-103.

rather than during the extreme movements.[106] By employing bivariate wavelet Dynamic Conditional Correlation GARCH model, Khalfaoui was able to entangle oil's and gold's time varying nexus and inspected the relationship between the variables before, during and after the GFC in his work from 2018. His research contributed results that imply that between oil and gold exists a positive relationship across different frequencies, whereas it diverges in the mid and long run horizons throughout the periods of market turmoil. This indicates that oil is not always affecting gold's price.[107] Oil can serve even as a hedge for precious metals, i.e. gold, silver, platinum, and palladium, as evidence from DCC-GARCH model analysis performed by Mensi et al. shows. There exist dynamic, asymmetric, conditional correlations between the returns of precious metals' futures and Brent oil, whereas the values of correlations swing between positive and negative values and are most vulnerable during significant market developments. The combination of oil and gold is proven to be most successful during the periods of GFC and ESDC, while long oil, short gold has been effective also throughout Asian financial crisis and COVID crisis. Gold exhibited substantial hedge potential during the burst of dot-com bubble, pre and during GFC and ESDC and also during Great Oil Bust period from 2014 to 2019. Consequently, gold was replaced by platinum in hedging effectiveness during COVID crisis.[108] Mokni et al. provide evidence in their research by utilizing time-varying parameter VAR model in combination with certain spillover measures, that among gold and oil prices, there exists on average weak dynamic connectedness, however during the market turmoil, such as Asian financial crisis, GFC and ESDC, the connectedness may increase. The relationship of these variables is highly sensitive to inflation, political news, e.g. partisan conflict, and crisis in general. Oil supply shocks induce response in gold market primarily, followed by oil risk shocks, while oil demand shocks are net volatility spillover receivers from gold market. The results further imply that during normal oil market conditions, gold can serve as a safe haven and hedge in case of oil shocks, however, when the conditions become more tumultuous, gold's ability ceases.[109] A recent study by Tanin et al. from 2022 utilized nonlinear ARDL on the data spanning from May 2007 until August 2021, and yields challenging evidence towards the

[106] SHAHBAZ, Muhammad et al. Does oil predict gold? A nonparametric causality-in-quantiles approach. In *Resources Policy* [online]. 2017, 52: 257-265.
[107] KHALFAOUI, Rabeh. Oil–gold time varying nexus: A time–frequency analysis. In *Physica A: Statistical Mechanics and its Applications* [online]. 2018, 503: 86-104.
[108] MENSI, Walid, et al. Oil and precious metals: Volatility transmission, hedging, and safe haven analysis from the Asian crisis to the COVID-19 crisis. In *Economic Analysis and Policy* [online]. 2021, 71: 73-96.
[109] MOKNI, Khaled, et al. Does economic policy uncertainty drive the dynamic connectedness between oil price shocks and gold price?. In *Resources Policy* [online]. 2020, 69: 101819.

existing literature. In the wake of the recent development, oil prices have supposedly lost the power to predict gold's price, and within the examined time span, price linkage between the assets was not functional during all examined crisis intervals. Short term positive effects of oil prices decline on gold manifested during COVID crisis and gold market crash. They also provide contrasting evidence that before COVID, there is no link between Brent oil prices and gold. They contradict the notion of positive relationship between the variables and dispute any long-term relationship between them. In conclusion, the oil induced changes in gold's returns are time and event depending. Contrary to other researchers' findings, who performed their inference on the COVID crisis period, they find supportive evidence for gold being a safe haven during this interval.[110]

1.2.1.8 Silver

The intimate relationship between gold and silver has been almost eternal. They both have seen their vast usage in jewelry, industrials and also like a form of investment and monetary vehicles. Therefore, a question arises, whether the relationship between them is also of mutually influencing nature, or they just fulfill similar roles in our world. In 2015, Lucey and Tuley took upon the challenge to examine, whether gold's and silver's relationship broke off in the 1990s, by utilizing recursive cointegration model, over the span of 25 years, from 1978 until 2002. On the given dataset, they observed preservation of the general relationship between the metals, however, there were periods, when the cointegration was weakened or not present.[111] On a broader dataset spanning from January 1970 to May 2015, a Residual Augmented Least Squares test was performed by Pierdzioch et al. in 2015, and they further confirm the findings of Lucey and Tuley, that is, the cointegration prevails, and even though in some period may be faded, the overall relationship is preserved. This also opens the room for a potential for predictability of the price development, to some extent, while the overall market efficiency is not violated.[112] In 2015 also Gil-Alana et al. performed an alternative modeling specification within a fractional integration framework, whereas they were examining the real prices of silver and gold on a yearly basis, between the years of 1833 until 2013 for gold, and 1792 until 2013 for silver.

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[110] TANIN, Tauhidul Islam, et al. Does oil impact gold during COVID-19 and three other recent crises?. In *Energy economics* [online]. 2022, 108: 105938.
[111] LUCEY, Brian M. and Edel TULLY. The Evolving Relationship between Gold & Silver 1978-2002: Evidence from Dynamic Cointegration Analysis. In *School of Business Studies, University of Dublin, Trinity College* [online]. 2015, 1.11.
[112] PIERDZIOCH, Christian et al. Cointegration of the prices of gold and silver: RALS-based evidence. In *Finance Research Letters* [online]. 2015, 15: 133-137.

They provide evidence that real gold prices do not exhibit mean reversion over the long run, while silver prices do. This leads to an implication that in case of exogenous shocks, the long-term memory of gold price inflation might potentially cause gold's further positive divergence from its previous real values, while in silver this effect is not expected.[113] Zhu et al. employed Quantile ARDL model in the year of 2016, in order to infer the relationship of gold and silver within the different settings of their returns distributions and found evidence that silver prices are more submissive to simultaneous changes in gold's price, predominantly at the tail quantiles. At the upper quantiles, constant cointegration relationship cannot be rejected, based on the evidence, while in the low tail quantiles, the relationship is more dynamic.[114] Furthermore, this kind of relationship is confirmed by Schweikert in 2018, who performed quantile cointegrating regressions and found supporting evidence for the notion of Zhu et al. Nonlinear, long-term relationship between the metals is present and is heavily asymmetric, while during the periods of market turmoil, the movement of the assets' prices becomes rather synchronized. In fact, more significant response of silver to gold's price changes is observed when silver price is relatively overvalued, and also more significant response of gold to silver's price changes when gold's price is relatively highly valued. This evidence together with visible comovement is present only during the periods of market turmoil and bubble-like periods, which might be caused by the desire of investors for safe haven properties possessed by both metals during these particular times.[115]

1.2.1.9 Currency

Currencies, respectively exchange rates and especially USD exchange rate, has particularly important position among gold price determinants. According to the estimates of IMF from 2008, from year 2002 until then, almost 40 % to 50 % of gold's price movement was related to the behavior of USD, "*with a 1% change in the effective external value of the dollar leading to a more than 1% change in the gold price*". The reason for this relationship is because gold is denominated in USD and when the dollar depreciates, the non-dollar currencies' purchasing power is on the rise, or vice versa in the case of dollar's appreciation, respectively. Moreover, in periods of USD downturn, there is a general demand for an asset

[113] GIL-ALANA, Luis A. et al. Trends and cycles in historical gold and silver prices. In *Journal of International Money and Finance* [online]. 2015, 58: 98-109.
[114] HUIMING, Zhu et al. Quantile behaviour of cointegration between silver and gold prices. In *Finance Research Letters* [online]. 2016, 19: 119-125.
[115] SCHWEIKERT, Karsten. Are gold and silver cointegrated? New evidence from quantile cointegrating regressions. In *Journal of Banking & Finance* [online]. 2018, 88: 44-51.

which can store value and gold provides this benefit, whereas consequently, when USD is appreciating, it is perceived as an adequate store of value by itself.[116] Numerous scholars tried to shed more light upon the intricate relationship between USD and gold. Reboredo and Rivera-Castro performed likelihood ratio test based on the data of USD and multiple other currencies' exchange rates in 2014 and provide evidence of consistent and positive correlation between gold and USD depreciation against various examined currencies. Moreover, the evidence suggests gold's role as a weak safe have for USD in case of heavy downturns of the currency. Therefore, gold's ability to hedge negative dollar movements to a certain extent provides investors and central banks with an alternative diversifying and protective option.[117] Later in 2015 Beckmann et al. employed GARCH-in-mean-SVAR models to infer general relationship of gold and currencies. The evidence suggests that from all currencies' exchange rate depreciations, initially negative effect manifests on the price of gold after one day, which then changes into positive one after two days on average. Their evidence also supports the notion that gold price denominated in the USD tends to rise after USD's depreciation, with the increase in volatility of USD exchange rates resulting in stronger hedging ability of gold.[118] The thesis for the relationship between the variables is furthermore supported by the work of Gozgor et al. from 2019, where they provide evidence for the notion that gold's price is influenced by changes in USD's real effective exchange rate.[119] In 2022 Chiang in his study used Generalized Error Distribution GARCH model to comprehensively examine the determinants of gold's price. Among other findings, his research yielded evidence of positive correlation between gold and exchange rate depreciation, no matter the currency denomination. Therefore, gold's inverse relationship with currencies holds to this day and could be utilized for portfolio diversification and hedging.[120]

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[116] ECONOMICS, Oxford. The impact of inflation and deflation on the case for gold. Commissioned by World Gold Council, 2011.
[117] REBOREDO, Juan C. and Miguel A. RIVERA-CASTRO. Can gold hedge and preserve value when the US dollar depreciates?. In *Economic Modelling* [online]. 2014, 39: 168-173.
[118] BECKMANN, Joscha et al. Causality and volatility patterns between gold prices and exchange rates. In *The North American Journal of Economics and Finance* [online]. 2015, 34: 292-300.
[119] GOZGOR, Giray, et al. The role of uncertainty measures on the returns of gold. In *Economics Letters* [online]. 2019, 185: 108680.
[120] CHIANG, Thomas C. The effects of economic uncertainty, geopolitical risk and pandemic upheaval on gold prices. In *Resources Policy* [online]. 2022, 76: 102546.

1.2.1.10 Stocks

The question of gold being a safe haven is extensively researched, however it focuses more on the final effect, rather than the cause. The relationship between gold and stocks supposedly underwent major changes, which affect its dynamic and causality. In 2015 Choudhry et al. provided evidence from nonlinear causality tests performed on the daily data of three major stock indices, i.e. FTSE 100, S&P 500, and Nikkei 225, collected between January 2000 and March 2014. Their bi-directional approach yields results in support of non-existent or miniscule causality before GFC for all three stock markets. However, the relationship changes during the crisis and according to their results, gold loses safe haven ability in all of the examined countries.[121] Beckmann's et al. research from 2019 supports this notion, by stating that the relationship between gold and stocks, also bonds and exchange rates, increased after 2008, therefore losing the ability of being a safe haven.[122] The intensification of the relationships is further confirmed by the study of Baruník et al.'s study from 2016, where they caution against not carefully considered approach towards portfolio construction consisting of gold, oil and stocks. By utilizing DCC-GARCH model and wavelet approach, they were able to infer an emergence of positive homogenous correlations among the variables.[123] According to the research of Coronado et al. from 2018, causality between US stock, oil and gold markets exists in both ways, therefore one variable influencing the other and vice versa. It has nonlinear character and depends on the time sample specification, whereas in some periods it may diminish.[124] Furthermore, bidirectional causality between gold market and stock market is confirmed by the work of Tran and Nguyen from 2022, where they inspected comprehensively European and Asian stock markets during the COVID crisis period, from March to October 2021, by utilizing panel data vector autoregression. The evidence suggests, that in Asia and Europe, there was a negative effect of the stock market on gold during the inspected period, while in Asia investors were holding gold for the sake of utilization of its safe haven potential, in Europe

[121]CHOUDHRY, Taufiq et al. Relationship between gold and stock markets during the global financial crisis: Evidence from nonlinear causality tests. In *International Review of Financial Analysis* [online]. 2015, 41: 247-256.
[122] BECKMANN, Joscha et al. Gold price dynamics and the role of uncertainty. In *Quantitative Finance* [online]. 2019, 19.4: 663-681.
[123] BARUNÍK, Jozef et al. Gold, oil, and stocks: Dynamic correlations. In *International Review of Economics & Finance* [online]. 2016, 42: 186-201.
[124] CORONADO, Semei et al. An empirical analysis of the relationships between crude oil, gold and stock markets. In *The Energy Journal* [online]. 2018, 39.1_suppl: 193-208.

the investors diversified their portfolios between gold and foreign exchange reserves, with USD included, for this purpose.[125]

[125] TRAN, Oanh and Ha NGUYEN. The interdependence of gold, US dollar and stock market in the context of COVID-19 pandemic: an insight into analysis in Asia and Europe. In *Cogent Economics & Finance* [online]. 2022, 10.1: 2127483.

2 Objective of the thesis

The main objective of our master thesis is to assess and measure the influence of the economic shocks on the development of the price of gold within the US market environment. We identify economic variables which are influential in their relationship with gold within our specified framework and construct an econometric model, which is able to assess these influences, in order to interpret the magnitude of the economic shocks which are exhibited towards gold. We disclose the various characteristics of the researched variables and the gold itself and create a robust and stable model for qualitative estimation of the underlying relationships. To reach the main objective, we set up the following partial subobjectives:

- definition of the main topics within the research objective,
- data collection, refinement, transformation, and the time series construction from the historical prices of gold and its determinants,
- analyzing of the development of gold and its determinants,
- construction of multiple categorical and combined econometric models and their diagnostics in order to select the optimal combination and number of determinants for our research,
- construction of the main econometric model for the estimation of the coefficients of selected determinants of the gold's price,
- evaluation of the model and interpretation of the results.

3 Methodology and research methods

In the first chapter of our master thesis, we explored the existing academic literature and research findings in order to provide theoretical background for the topic of gold and its price determinants. In the second chapter we established our main goal and partial goals for achieving our main objective. In this chapter we disclose the method of our data selection, collection, refinement, and transformation. We also disclose the applied research methods and define our hypotheses.

3.1 Data description

In our master thesis, we consider 17 variables, from which one, gold's spot price, is the dependent variable, and the remaining 16 are the independent variables, which are presented more in detail in the table below. The data selection was based upon the literature which is focused on the research of the gold price and its determinants. The data was obtained from various sources, which are also relevant within the academic literature and are freely accessible and are more closely described in the following table no. 1. For the statistics of the search of the world "gold", we used Google Trends service, which effectively provides the trending of the online searches for specific words or sentences, with value of 0 indicating not enough data for given expression and value of 100 indicating the highest popularity of the given expression.

The final time series have in total n = 496 observations and consists of weekly values observed within the time span of 1st of October 2014 and 27th of March 2024. Initially, most of the data was obtained in more granular form, in daily frequency, however in order to find concurrence, we decided to use weekly frequency, because some time series are measured in a 7-day week format, while some, which are subject to the open hours of the market, are by standard in the 5-day week format. In this way, we were also able to cope with the situation of incompleteness of the daily data. Our main focus was the US market. For this purpose, we had to decide upon which particular day of the week to use, and we settled on Wednesday, because it is the middle of a week with the least number of closed-market days in our data. In case, of holiday taking place on Wednesday, and market being closed, we take the value of the previous day, i.e. Tuesday. After conducting statistical inference, we also decided whether to apply variable differentiation or transformation. The logarithmic transformations were used because of their interpretational abilities of the resulting

coefficients as a percentage changes and differentiation was employed because of control for stationarity.

Table No. 1: The description of variables.

Variable	Description of the variable	LN transformation	Differentiation	Source
GOLD	Gold Spot Price in USD	yes	yes	World Gold Council
GVZ	Cboe Gold ETF Volatility Index	yes	no	Chicago Board Options Exchange
SPX	S&P 500 Index	yes	yes	Yahoo Finance
VIX	Cboe Volatility Index	yes	no	Chicago Board Options Exchange
WTI	West Texas Intermediate Crude Oil Price in USD	yes	yes	Federal Reserve Economic Data
OVX	Cboe Crude Oil ETF Volatility Index	yes	no	Chicago Board Options Exchange
EPU US	US Economic Policy Uncertainty	yes	yes	Economic Policy Uncertainty
GPR	Global Geopolitical Risk Index	yes	no	Geopolitical Risk (GPR) Index
TNX	CBOE Interest Rate 10 Year T No	yes	yes	Yahoo Finance
SLV	iShares Silver Trust ETF in USD	yes	yes	Yahoo Finance
DNSI	Daily News Sentiment Index	no	no	Federal Reserve Bank of San Francisco
CPI	Consumer Price Index	no	no	Federal Reserve Economic Data
DXY	ICE US Dollar Index - Index	yes	yes	Yahoo Finance
BTC	Bitcoin Spot Price in USD	yes	yes	Yahoo Finance
DFF	Federal Funds Effective Rate	yes	yes	Federal Reserve Economic Data
GGT	Occurence of the word "gold" in google search	yes	no	Google Trends
ANFCI	Adjusted National Financial Conditions Index	no	yes	Federal Reserve Bank of Chicago

Source: Own processing, for the detail of the source of data used check the bibliography.

3.2 Methodology and hypotheses

In first, theoretical part of our master thesis we sourced information from the relevant academic sources and research papers. The theoretical part presented detailed introduction into the research topic, where we organized the selected information based on the method of analysis, and consequently connected the individual units by the method of synthesis.

To assess the influence of the economic shocks on the price of gold we use the method of induction in order to construct our hypotheses to be tested. Firstly, we gathered the data for the variables from the various freely accessible relevant sources and transformed them into the desired time format in the Microsoft Excel. Furthermore, we utilized the RStudio and Python software for statistical inference and data analysis. We used the method of categorization to divide our examined independent variables into four categories, mainly category of 'uncertainty measures', 'volatility measures', ''typical' market assets', and 'macroeconomic measures'. After we perform the initial statistical analysis, with the help of induction, we proceed to graphical analysis, correlational analysis, and empirical econometric models' construction. We performed a series of empirical experiments, where we used comparation and induction to assess the validity of each tested model. By utilization of the methodology of comparation based firstly on adjusted coefficient of determination and then testing for heteroskedasticity, autocorrelation, normality of the residuals, multicollinearity and model stability checks in terms of residual plot and M-fluctuation test, we were able to select the optimal main econometric model configuration. Consequently, by the method of induction and deduction, we interpret the results of our econometric model and inference and evaluate our findings.

Our econometric model is the so-called short-run ARDL (p, $q_1, \ldots, q_k$) model with k independent variables, the general form can be written as follows:

$$y_t = c_0 + c_1 t + \sum_{i=1}^{p} b_{y,i}\, y_{t-1} + \sum_{j=1}^{k} \sum_{l=0}^{q_j} b_{j,l} x_{j,t-1} + \epsilon_t$$

where:

- y_t is the dependent variable, i.e. gold, at time t;
- c_0 is the intercept;
- $c_1 t$ is the trend component of the model, or slope respectively, at time t;
- $\sum_{i=1}^{p} b_{y,i}\, y_{t-1}$ represent the lagged values of the dependent variable from i = 1 up to p, where p is the maximum lag considered by the model, $b_{y,i}$ represent its corresponding coefficient;
- $\sum_{j=1}^{k} \sum_{l=0}^{q_j} b_{j,l} x_{j,t-1}$ represent the lagged values of the independent variables x_j, while the outer sum extends from j = 1 up to k, where k is the number of independent variables in the model, and the inner sum extends from l = 0 up to q_j, where q_j is the maximum lag order considered for j-th independent variable, and consequently, each lagged value of x_j is multiplied by its corresponding coefficient $b_{j,l}$;

- ϵ_t is the error, or disturbance term at time t. [126]

ARDL model provides convenient way to work with the non-stationary variables, respectively variables which are I(0) or I(1) stationary in combination, incorporates lagged values, therefore allows for horizontal time-influence estimation, can capture both short run and long run dynamics among the variables and provides insights into the direction of the causality of the variables, by analyzing the signs of the coefficients and their significance. The overall mechanics of the model allows for capturing of dynamic relationships between the dependent and independent variables, as well as their lagged values.[127]

We decided to apply particularly the short-run version of the ARDL model, because we wanted to focus on the short-run dynamics between the variables, in order to provide potential insights for investors, which could help in their decision making during the normal and also irregular short time fluctuations on the market and utilize the provided information for incorporation into their trading strategies. Besides, other viable model alternatives might come from the family of Vector Autoregression models, Generalized Autoregressive Conditional Heteroskedasticity models, other distributed lag models and also non-linear ARDL model, or standard ARDL model might be used.

Our hypotheses are the following:

Hypothesis No. 1: *At least one of the variables' group is represented in the model by one or more determinants with statistically significant and robust results.*

Hypothesis No. 2: *Search of the word "gold" on the Google has influence on the gold's price.*

Hypothesis No. 3: *Aggregate metrics reflecting the economic and financial conditions have influence on the price of gold.*

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[126] NATSIOPOULOS, Kleanthis and Nickolaos G. TZEREMES. ARDL bounds test for cointegration: Replicating the Pesaran et al.(2001) results for the UK earnings equation using R. In *Journal of Applied Econometrics* [online]. 2022 Aug;37(5):1079-90.

[127] PESARAN, M. Hashem, et al. An autoregressive distributed lag modelling approach to cointegration analysis. In *Cambridge, UK: Department of Applied Economics, University of Cambridge* [online]. 1995.

4 Results

This chapter discloses the results of our work, whereas we conduct various approaches to address the topic of ARDL modelling, optimal variable selection and model construction. The chapter is divided into 3 subsegments, where we perform graphical analysis, correlational analysis and then proceed to short-run ARDL model construction and optimalization of its parameters.

4.1 Development of gold's price and its determinants

In order to properly address the influence of various economic shocks on the price of gold, which we assume that might manifest trough the fluctuations in the values of the chosen determinants of the metal's price, we first performed graphical analysis of the data of the corresponding variables.

First and foremost, as we can observe on the graph no. 1 below, within the research period in question, gold's nominal price has doubled. The period from the October 2014 until roughly beginning of the June 2019 induces an impression of relatively stable price channel within certain bounds, whereas at the beginning of the summer of 2019, we observed a structural shift in the properties of the gold's price. Various factors influence the price of gold, but based on the theory, and as we further show in our work, there exists some correlational relationships between the variables in question, and therefore we assume that the gold's price development within the researched period is influenced by some of the examined variables to a certain extent. As also academic literature and research points out, there exists a significant relationship between oil and gold, and indeed, from the year 2014 until 2016 the oil price declined, and with it, gold did too. Besides that, several geopolitical events took place during the time, for instance ongoing war in Syria and Ukraine, European refugee crisis during the year of 2015, Iran Nuclear Deal in July 2015, Brexit referendum held in the UK in June 2016, Donald Trump becoming a president of the USA at the beginning of January 2017, and also the aftermath of the European debt crisis and zero lower bound monetary policy in Europe and de facto also in the US and Japan, just to name a few. The year of 2019 went in the name of escalation of the trade war between USA and China, Brexit uncertainty, or fears of global economic slowdown, which might have affected the price of gold. But most significantly, from the beginning of the year 2020, the COVID crisis impacted the gold's price heavily. The reason to consider the aforementioned events to have a potential impact on the gold's price is because, as according to the academic literature,

gold definitely was perceived as a safe haven during the time in question. Later on, during the second half of the examined period, from the price development of gold we can observe an increase in its relative volatility, compared to the first half of the dataset. The aftermath of COVID crisis, the full-scale invasion of Ukraine, inflationary pressures and everlasting fear of economic slowdown, collapse of Silicon Valley Bank and a lot more events potentially could have affected the behavior of the metal's price and despite the partial splits in the opinion of whether gold still remains a safe haven in the academic literature, graphical analysis suggests its general growing trend responds positively to increase in measures which quantify economic and geopolitical situation.

Graph No. 1: Development of the spot price of gold in USD within the researched period.

Source: Own processing in MS Excel, for the detail of the source of data used check the bibliography.

The determinants of the price of gold which were subject to our research can be divided into four subgroups and were selected based on the existing literature examining the determinants of the gold price.

First subgroup consists of uncertainty measures, such as the Economic Policy Uncertainty in the US (EPU US) which is based on the Baker et al.'s research[128], the Global Geopolitical Risk developed by Caldara and Iacoviello (GPR)[129], the sentiment analysis derived from economic and financial newspapers, developed by Shapiro et al. (DNSI)[130], Chicago Fed's Adjusted National Financial Conditions Index (ANFCI)[131] and the occurrence of the word "gold" in the Google search service (GGT).

[128] BAKER, Scott R. et al. Measuring economic policy uncertainty. In *The quarterly journal of economics* [online]. 2016 Nov 1;131(4):1593-636.
[129] CALDARA, Dario and Matteo IACOVIELLO. Measuring geopolitical risk. In *American Economic Review* [online]. 2022 Apr 1;112(4):1194-1225.
[130] SHAPIRO, Adam Hale et al. Measuring news sentiment. In *Journal of econometrics* [online]. 2022 Jun 1;228(2):221-43.
[131] BRAVE, Scott A. and David KELLEY. Introducing the Chicago fed's new adjusted national financial conditions index. In *Chicago Fed Letter* [online]. 2017, 386: 2017.

Second subgroup consists of volatility measures, specifically the gold's physically backed ETF GLD volatility measure (GVZ), S&P 500 index's volatility measure (VIX) and the West Texas Intermediate crude oil's ETF USO volatility measure (OVX).

Third group is composed from the 'typical' market assets, specifically from S&P 500 Index (SPX), West Texas Intermediate crude oil spot price (WTI), physically backed silver ETF (SLV) and Bitcoin's spot price in USD (BTC).

Fourth and last group was composed from the 10-year Treasury Yield Index (TNX), Consumer Price Index (CPI), US Dollar Index (DXY) and Federal Funds Effective Rate (DFF).

4.1.1 Uncertainty measures

On the linked graph no. 2 depicted below we inspected various uncertainty measures, from which generally all of them exhibited certain similarities. For most of them, there is a clear reaction to the inception of the COVID crisis, with the EPU US, DNSI, ANFCI and GGT reacting clearly to the global turmoil induced by this event. Besides that, we register spikes in some indices due to the geopolitical events, like Hamas attacking Israel or Russia invading Ukraine. The graphical convergence of such events displayed on the graphs with the gold's price suggests there might exist a relationship between the variables. For instance, before the invasion, from the beginning of February 2022, gold rose cumulatively by 5.5 % in three weeks, and additionally, after the 24th of February, for more than 4.3 % in the next two weeks, which cumulatively accounted for the total rise of almost 10 %. Afterwards, in the middle of March, its price declined slightly. GPR grew cumulatively from the mid of February by almost 150 % in three weeks but declined shortly after the beginning of March. In February, the search for gold grew by 32% compared to previous month, and DNSI declined by almost 220 % in four weeks from the invasion. Similar spikes, except for GGT, occurred also after Hamas' attack on Israel.[132] Based on the similarities of movement between these variables and gold's price, we assumed there would be potential to explain gold's price development. In the context of spike in EPU US, gold seems to respond with a certain degree of belatedness. When compared to GPR, gold seems to respond positively, however, depending on the magnitude of shock caused by geopolitical event. Small negative comovement might be observed in its relationship towards DNSI, mainly during the COVID

[132] We are using percentual changes expressed by the natural logarithm return, i.e. $\ln(t_0/t_{-1})$.

inception period and the same, but in a positive way goes for the ANFCI as well. In the case of GGT, we observe a late response of GGT to the price of gold, rather than vice versa. Significant shocks are observed on all graphs, except for GPR, after the WHO declared COVID-19 a pandemic on March 11th, 2020. Interestingly enough, the GGT spiked around the time when COVID crisis began, and also roughly around the time when there was an anticipation of the oncoming COVID wave, or during the ongoing waves.

The logic of EPU US and GPR is that when the economic policy uncertainty and geopolitical risks are higher, the indices reflect it by returning higher values. EPU US is composed from four components, first is an index composed from search results for certain words in 10 large newspapers in the US, second is tax expirations index in the US, then followed by CPI forecast disagreement measure and fourth component is federal, state and local purchases disagreement measure.[133] GPR utilizes the automatic text-search results from the electronic archives of 10 newspapers, while looking at 8 various categories related to the geopolitical risks.[134] Similarly, DNSI examines 24 largest US newspapers, while measuring for statistical significance of information related to economics, within the news. It has geometrically declining weights assigned to the data, which decrease with time since the article publication. It oscillates around 0, with positive values reflecting positive sentiment, and negative values reflecting negative sentiment.[135] The ANFCI is constructed with the mean of 0 and a standard deviation of 1, whereas positive values reflect period when financial conditions are more restricted that would be expected from the current macroeconomic conditions, while negative values suggest looser conditions.[136] GGT is a reflection of the search of the word "gold" within specified weekly time frame ranging from 28th September 2014 until 30th March 2024. The values range from 0 to 100, based on the interest for the word within the time frame. Maximal value represents maximal interest in terms of frequency of search for the word, while minimal value represents the opposite.[137]

Graph No. 2: Development of uncertainty measures within the researched period.

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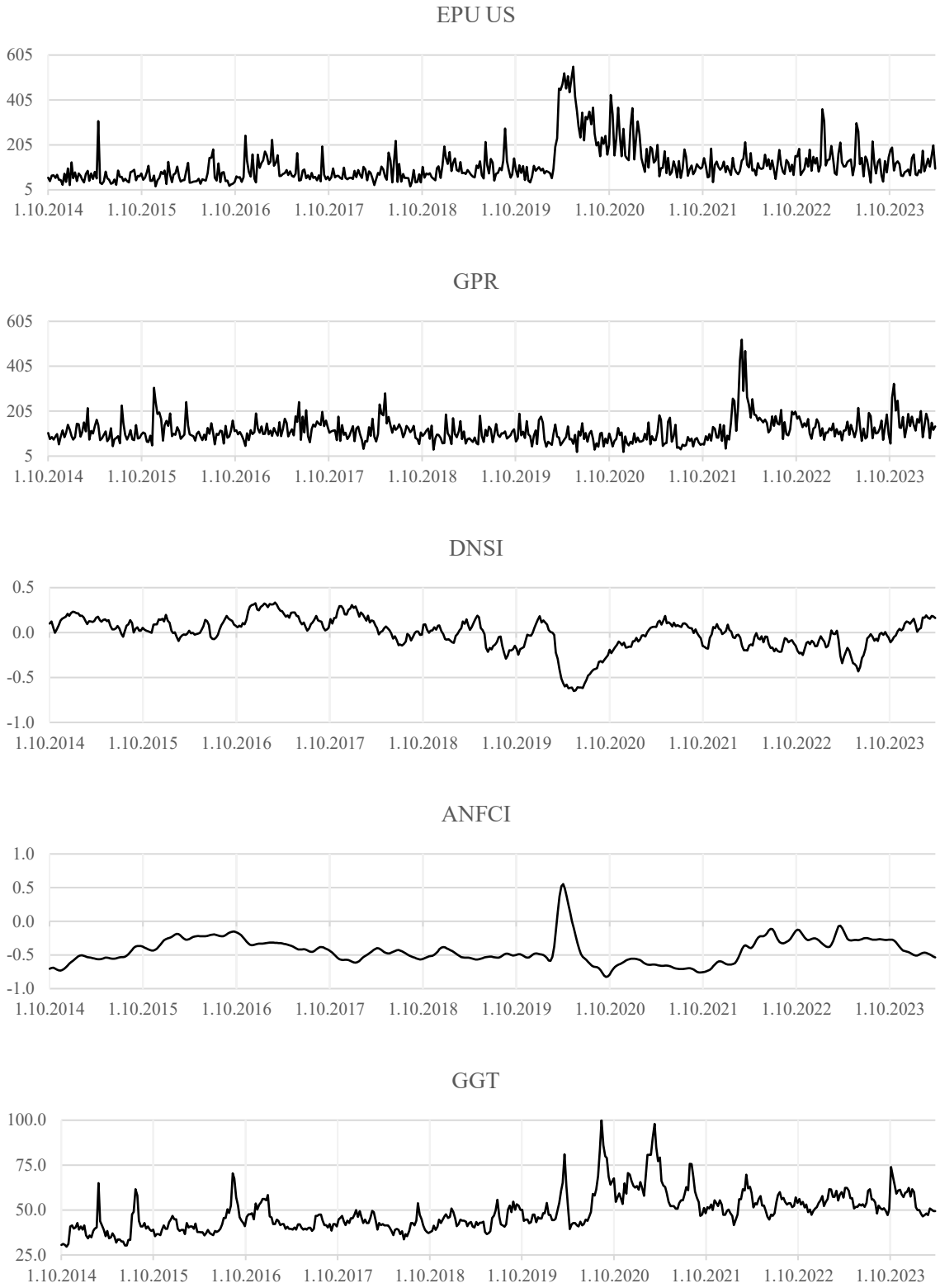
[133] ECONOMIC POLICY UNCERTAINTY. 2024. *US EPU* [online]. EPU, 2024. [cited 2024-04-09]. Available on the internet: http://www.policyuncertainty.com/us_monthly.html

[134] GEOPOLITICAL RISK INDEX. 2024. *Geopolitical risk (GPR) Index* [online]. GPRI, 2024. [cited 2024-04-09]. Available on the internet: https://www.matteoiacoviello.com/gpr.htm

[135] FEDERAL RESERVE BANK OF SAN FRANCISCO. 2024. *Daily News Sentiment Index* [online]. FRBSF, 2024. [cited 2024-04-09]. Available on the internet: https://www.frbsf.org/research-and-insights/data-and-indicators/daily-news-sentiment-index/

[136] FEDERAL RESERVE BANK OF CHICAGO. 2024. *Adjusted National Financial Conditions index* [online]. ANFCI, 2024. [cited 2024-04-09]. Available on the internet: https://www.chicagofed.org/research/data/nfci/current-data

[137] GOOGLE TRENDS. 2024. *"gold"* [online]. GT, 2024. [cited 2024-04-09]. Available on the internet: https://trends.google.com/trends/explore?date=2014-09-28%202024-03-30&q=gold&hl=sk



Source: Own processing in MS Excel, for the detail of the source of data used check the bibliography.

4.1.2 Volatility measures

Volatility measures, similar to uncertainty measures, are inspected due to the reason of their ability to potentially capture events which diverge from the 'normality' quite well.

To diverge from normality means in this context, that when certain event, which is related to the assets in question, of a relatively greater magnitude happens, the impact is transmitted on the values of the volatility measures. Based on the academic research and literature we know that not only economic, but also geopolitical and other types of events influence the market and assets traded on the market. By graphically examining the volatility measures, as is depicted on the following graph no. 3, we once again identified certain similarities which are relevant to the examined period, especially the notorious COVID crisis. Interestingly enough, from the graphical inspection it is evident, that there has been higher frequency of volatility spikes, particularly after this event. Even though GVZ spiked roughly during the time when WHO declared global pandemic state of emergency, gold reacted with a certain delay. When additionally compared to VIX, we noticed that during the years of 2020 – 2021, there was higher volatility levels in both volatility measures, but also in the gold's price itself, which potentially indicates the connection between stock market uncertainty and gold. After 2020 we also observed a potential lagged response of gold towards the heightened oil volatility, while before this period it is not so evident. Even though the developments of the volatility measures seem to be very similar to each other at the first glance, we decided to inspect each and every one of them, in order to potentially identify, whether for example VIX can better predict significant changes in gold, than gold's volatility itself.

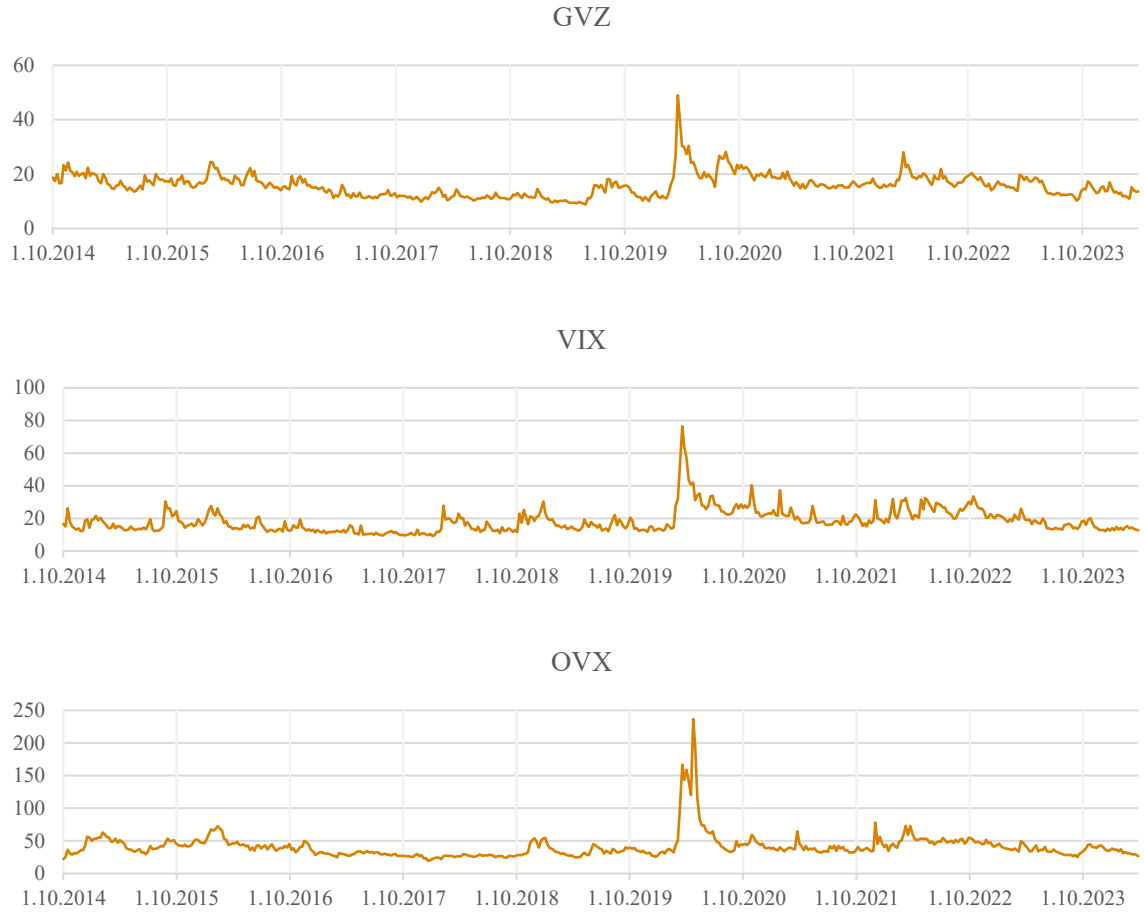
The logic for the computation of these indices is similar, as they are all product of Chicago Board Options Exchange, and use the same methodology for the calculation. GVZ is a numerical estimator of the anticipated 30-day volatility of returns of the physically backed gold ETF (GLD), where GVZ is calculated by interpolation of two, time-weighted sums of option mid-quote values, whereas the annualization of the interpolated value, on which square root is applied, and the result is expressed in percentage points.[138] VIX, which represents the expected volatility of S&P 500 Index is obtained by the same metrics and is considered to be the reflector of the 'market fear'.[139] OVX is calculated by the same methodology, but the underlying assets are the options for USO ETF, which is constructed

[138] CBOE. 2024. *Cboe Gold ETF Volatility Index* [online]. GVZ, 2024. [cited 2024-04-09]. Available on the internet: https://www.cboe.com/us/indices/dashboard/gvz/

[139] CBOE. 2024. *Cboe Volatility Index* [online]. VIX, 2024. [cited 2024-04-09]. Available on the internet: https://www.cboe.com/us/indices/dashboard/vix/

to mimic the daily changes in percentage terms of WTI crude oil traded in Cushing, Oklahoma.[140]

Graph No. 3: Development of volatility measures within the researched period.



Source: Own processing in MS Excel, for the detail of the source of data used check the bibliography.

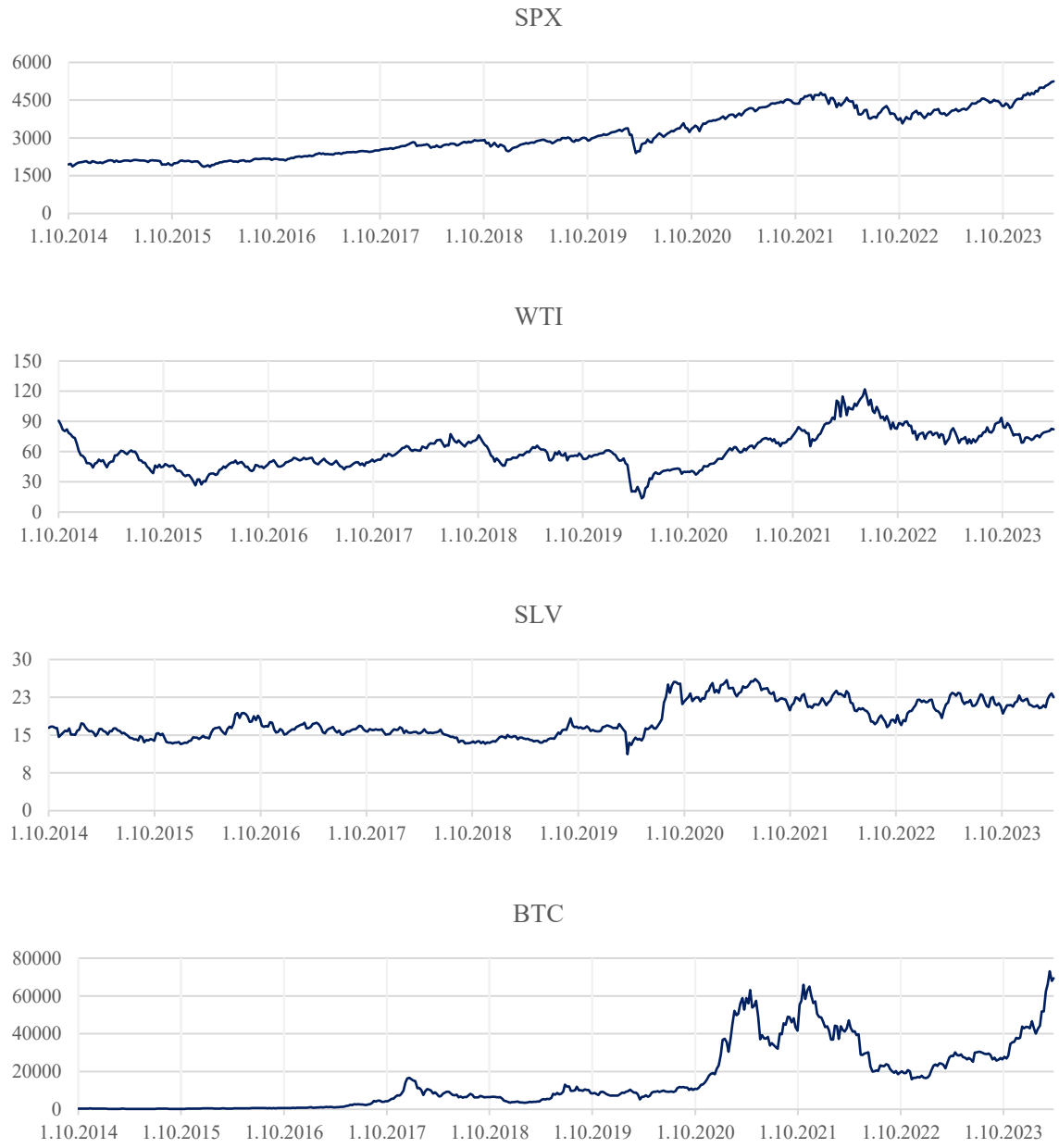
4.1.3 'Typical' market assets

The use of the word 'typical' in the context of our research means that these assets are often times in the academic literature referred to as the determinants of the price of gold, therefore can be considered as shocks emitters towards gold prices. Indeed, on most of the individual graphs aggregated in the graph no. 4 depicted below, except for Bitcoin, we observe quite similar, but asymmetric patterns when compared to gold's price development, especially the response to COVID crisis inception. With the decline in oil price at the beginning of the researched period, we also see a subtle response in gold, although not in the same magnitude. On the graph for silver backed ETF SLV, we observe, that on the contrary

[140] CBOE. 2024. *Cboe Crude Oil ETF Volatility Index* [online]. OVX, 2024. [cited 2024-04-09]. Available on the internet: https://www.cboe.com/us/indices/dashboard/ovx/

to the gold, its behavior seems to be more of mean reverting, but reactive to the movement of SPX and WTI in negative way. Gold, when compared to these assets reacts in times of decline of SPX and WTI negatively, which might imply its safe haven property, however the relationships between all of the researched variables are not static and change preliminarily. By some scholars, Bitcoin is beginning to be considered as a potential safe haven asset because of its decentralized nature, and indeed, we might observe some similar comovement after the spring of 2020.

Graph No. 4: Development of 'typical' market assets within the researched period.

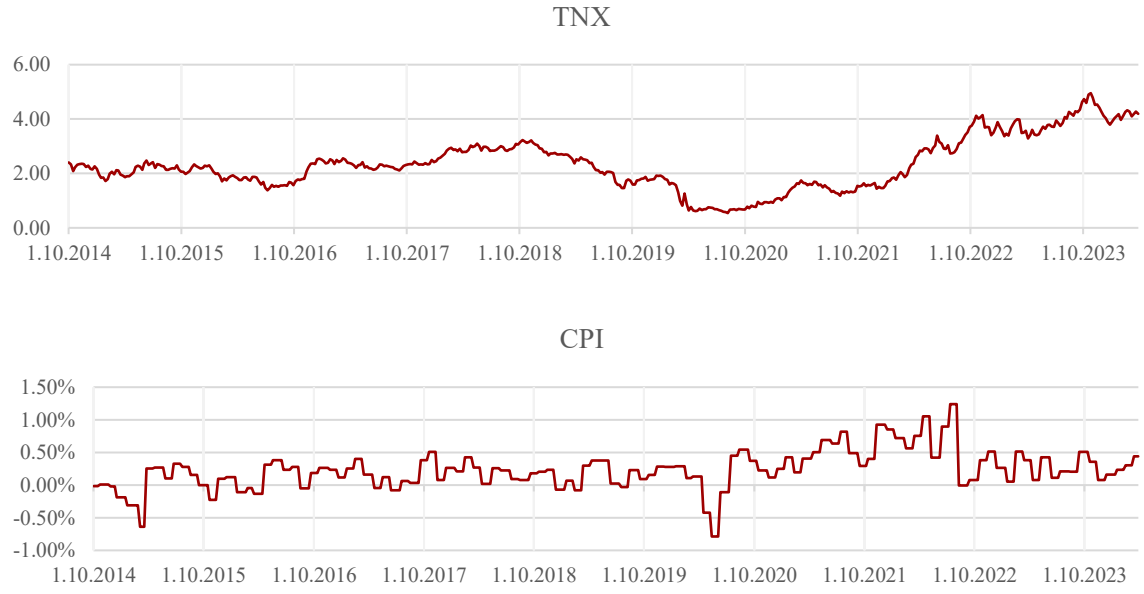


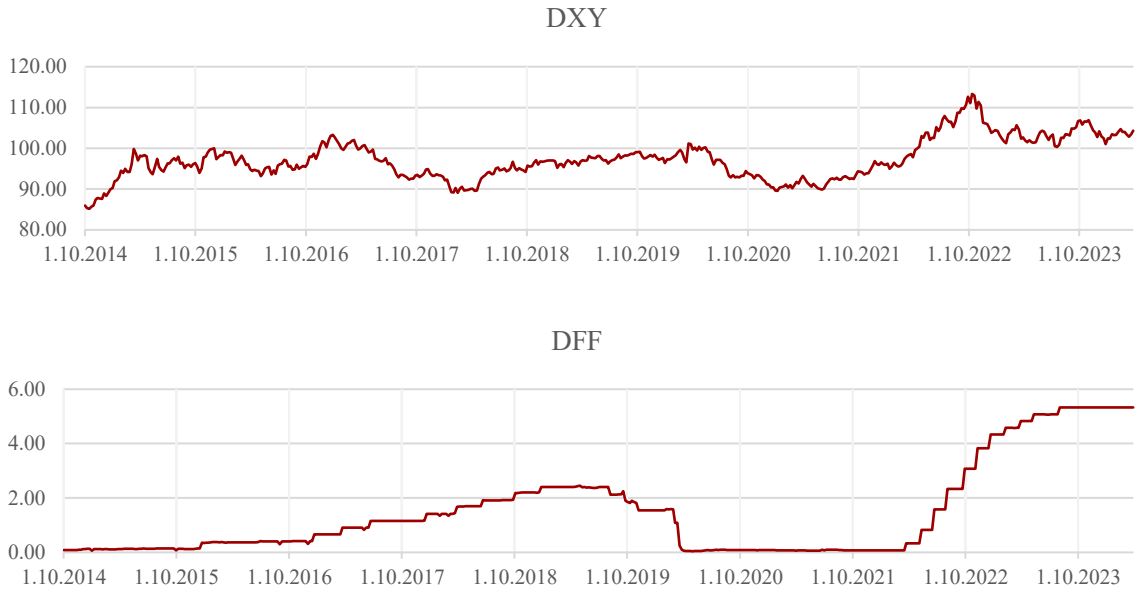
Source: Own processing in MS Excel, for the detail of the source of data used check the bibliography.

4.1.4 Macroeconomic measures

The last subgroup of potential determinants is composed of four macroeconomic measures, which might affect investors' behavior towards gold and therefore influence its price. From our research into the academic literature, we know that gold has various relationships with the macroeconomic metrics such as CPI, or currencies, especially US dollar. By graphical inspection on the graph no. 5, we observed relatively inverse relationship of gold and the US 10-year Treasury Bond yield, which supports the notion of gold being able to partially complement the bond during the time it loses its attractiveness. The CPI measure is generally considered by the market in percentual change form, therefore we employed natural logarithmic change between the given period, respectively, since it is a monthly measure, we accommodated it to the weekly frequency in order to inspect whether the 'jumps' in terms of publishing the CPI results have a potential effect on gold. By graphical inspection we observed a negative relationship between the two variables, which could be justified by the fact that during higher growth of inflation, US dollar gets stronger, and it is negatively correlated with gold, therefore CPI might also exhibit negative influence on gold. Comparison with US dollar index supports this notion, as the negative relationship is graphically evident, the result which is also found within the works of many scholars. Federal funds effective rate seems to move negatively with respect to gold only during the time of rapid rate hikes, otherwise there seems to be no relationship, however due to its indirect connection to US dollar, in which gold is denominated, we decided to explore for this relationship too.

Graph No. 5: Development of macroeconomic measures within the researched period.





Source: own processing in MS Excel, for the detail of the source of data used check the bibliography.

After the graphical inspection of the variables within all four categories, we concluded that some of them exhibit strong trend and change within their respective means and variances, and these might be subject to differentiation in order to ensure their stationarity.

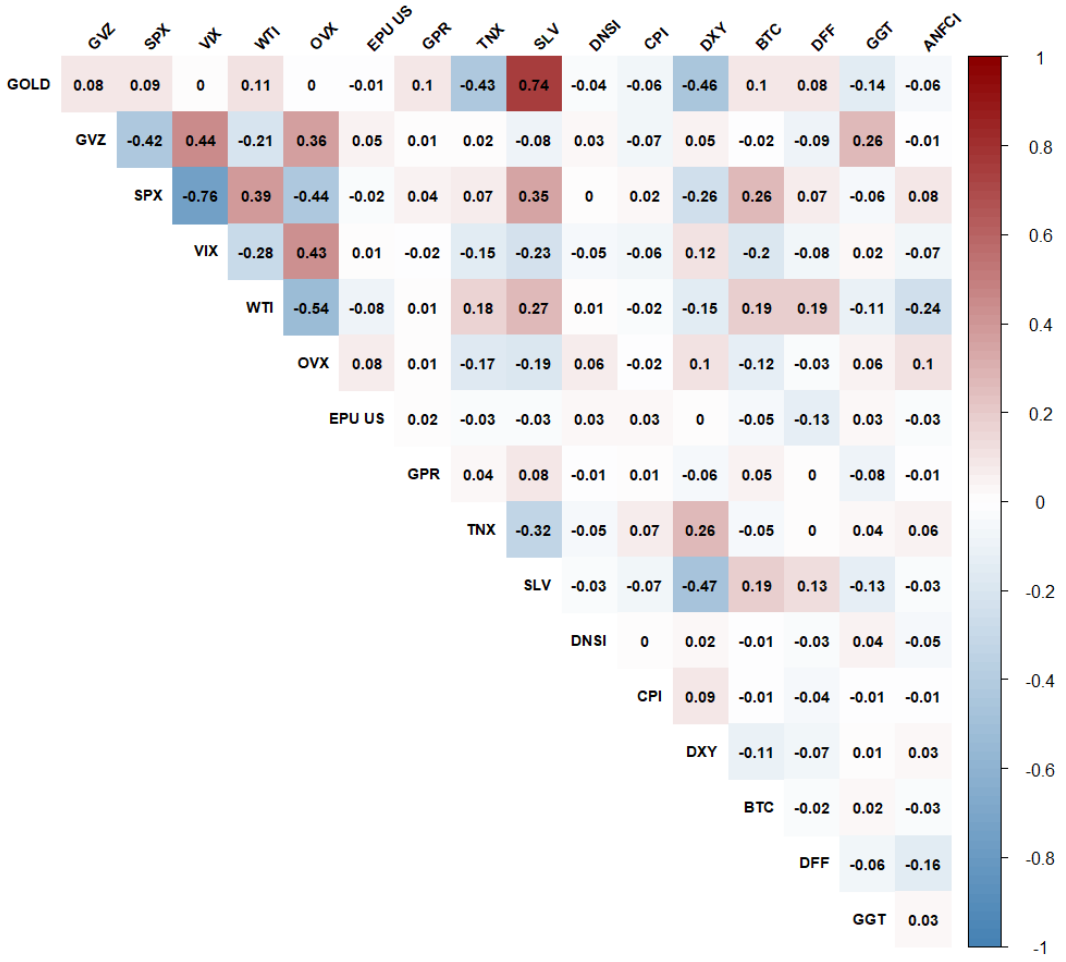
4.2 Correlation analysis

To get more closer understanding of the relationships between the variables in question, we further conducted a correlation analysis. Pearson's correlation can only capture linear relationships, not the slope or nonlinear relationships, but provides a relevant information on the average direction of the linear connection between the examined quantities over a specified period. Furthermore, it can offer more comprehensive view into the depth of the connection among the inspected elements. However, we must bear in mind that correlation does not imply causality.

On the correlation diagram represented by the graph no. 6 below are depicted the correlations of the natural logarithm changes over the sample period n-1, because in this way we can capture the overall relationship on the same level. With gold, we observed strong positive relationship with silver, which is not surprising, as both are precious metals, and even though they have relatively different uses, they are still real assets which can be physically hold onto. Gold exhibits relatively potent negative connection with TNX and DXY, which further supports the notion of the gold and US dollar being negatively engaged. Interestingly enough, gold does not exhibit linear relationships with the volatility measures,

nor uncertainty measures, except for the GPR, where there is a slight indication of the connection between the elements, same as for BTC, OIL, DFF, GVZ and SPX. Interesting relationship arises between the search of the term "gold" worldwide and the gold's volatility measure, while it is negative with the gold itself. Silver exhibit similarity with gold with respect to the US dollar variables and also seems to have stronger linear connection with the stock market and crude oil, therefore might not be such a valuable hedge in case of need for these assets, which is in line with the academic research findings. The upper left cluster of stronger correlations represent the relationship between the CBOE volatility measures and their respective direct and indirect sources. With gold being the only exception in having concrete linear associations with the subject variables, we can see that gold's volatility relatively strongly and negatively responds to SPX and WTI movements, while the volatilities seem to be well connected with each other. It is important to note that no correlation, i.e. around zero, does not imply that there is no connection among the variables, it just means that there is no linear link between them over the specified period.

Graph No. 6: Correlation diagram between the researched variables.



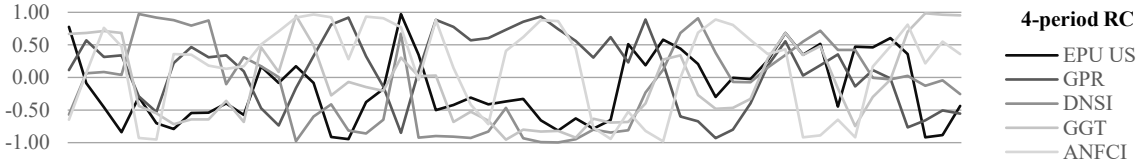
Source: own processing in RStudio, for the detail of the source of data used check the bibliography.

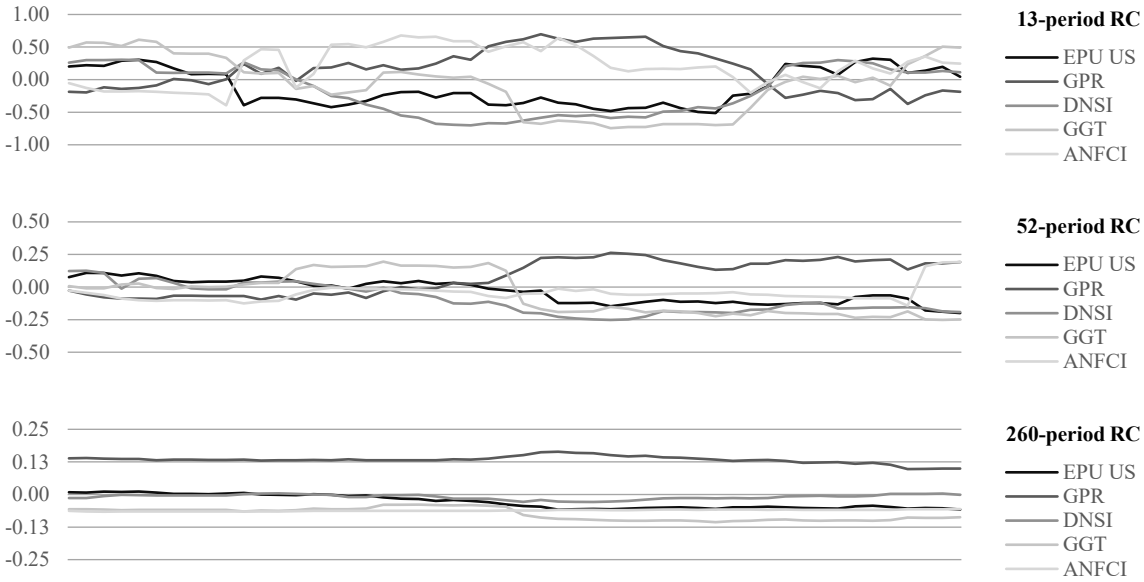
Since the correlation diagram captures only the whole period, we decided to take out the sample of the rolling correlations between gold and other researched elements from the last 52 observations, in order to understand more comprehensively their relationships with gold in the recent period. Rolling correlation is used to capture the dynamic linear relationship between the variables over time, more specifically over a specified rolling window. It calculates the correlation coefficient within a moving window that advances one period at a time. The 52 observations represent roughly one year span, and on this sample, we wanted to demonstrate how the links between gold and the examined variables change on different timescale. This can potentially provide more insight into the linearity and direction of the links between them, an understanding, which could be then expanded on the whole sample, on average.

We decided to pick 4-period, 13-period, 52-period, and 260-period rolling correlations for approximating the 1-month, 1-quarter, 1-year and 5-year periods, in order to demonstrate the depth of the linearity among the variables, an insight, which correlational diagram was unable to capture, because it is only displaying the values for the whole sample span.

On the following graph no. 7, we observe multiple period-varying rolling correlations for the uncertainty measures. The purpose of this method of analysis is to note, that at the higher frequency, or shorter time frame respectively, the variables exhibit quite dynamic relationships with gold, which changes chaotically. As we move trough lower frequencies, the relationships start to stabilize more, and it becomes clearer that which of the variables have the potential to be linearly measured in its relationship with gold. Except for 4-period graph, on all the others, GPR exhibits relatively stable positive linear connection with gold. For the other variables, as we move towards lower frequencies, the correlation tends to oscillate around zero, indicating, that nonlinearity might be present within these relationships with gold.

Graph No. 7: Rolling correlations of various periods for the uncertainty measures.

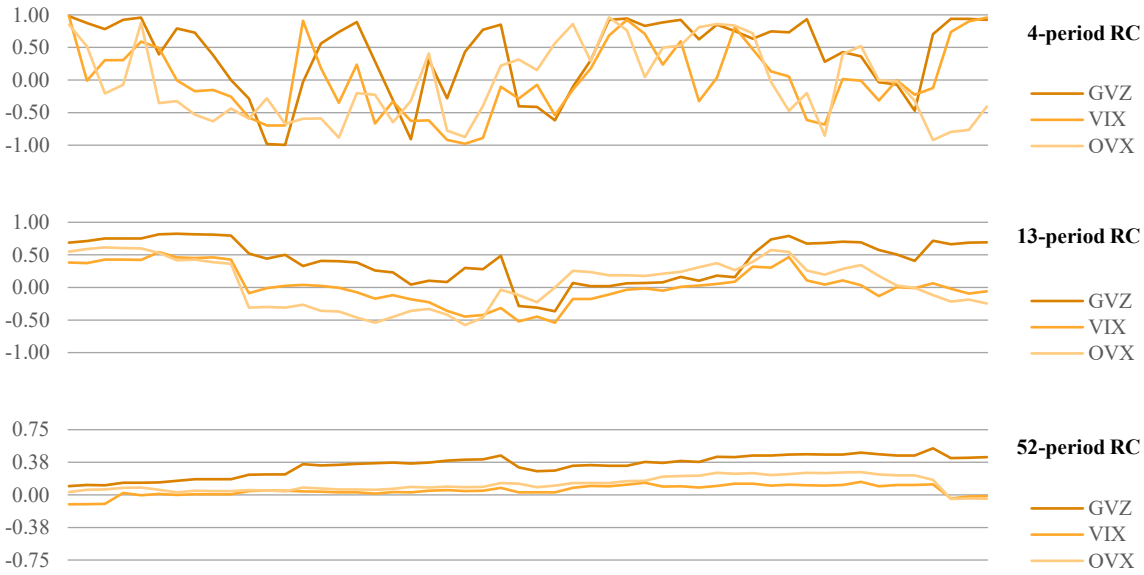


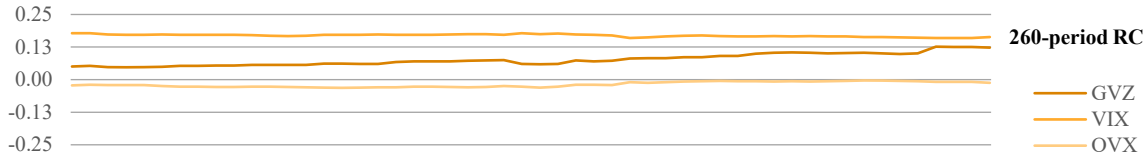


Source: own processing in MS Excel, for the detail of the source of data used check the bibliography.

On the graph no. 8 we displayed rolling correlations of the uncertainty measures, and we observed that on the 52-period GVZ exhibit relatively stable positive linear relationship with gold. OVX and gold seem to have no linear connection over the lower time frequencies, while interestingly, VIX exhibits little stronger linear connection on the 260-period in the last year, than GVZ, although the values are on average, low. This implies, that linear link among volatilities and gold is not very tangible, therefore there exists potential for nonlinear examinations.

Graph No. 8: Rolling correlations of various periods for the volatility measures.

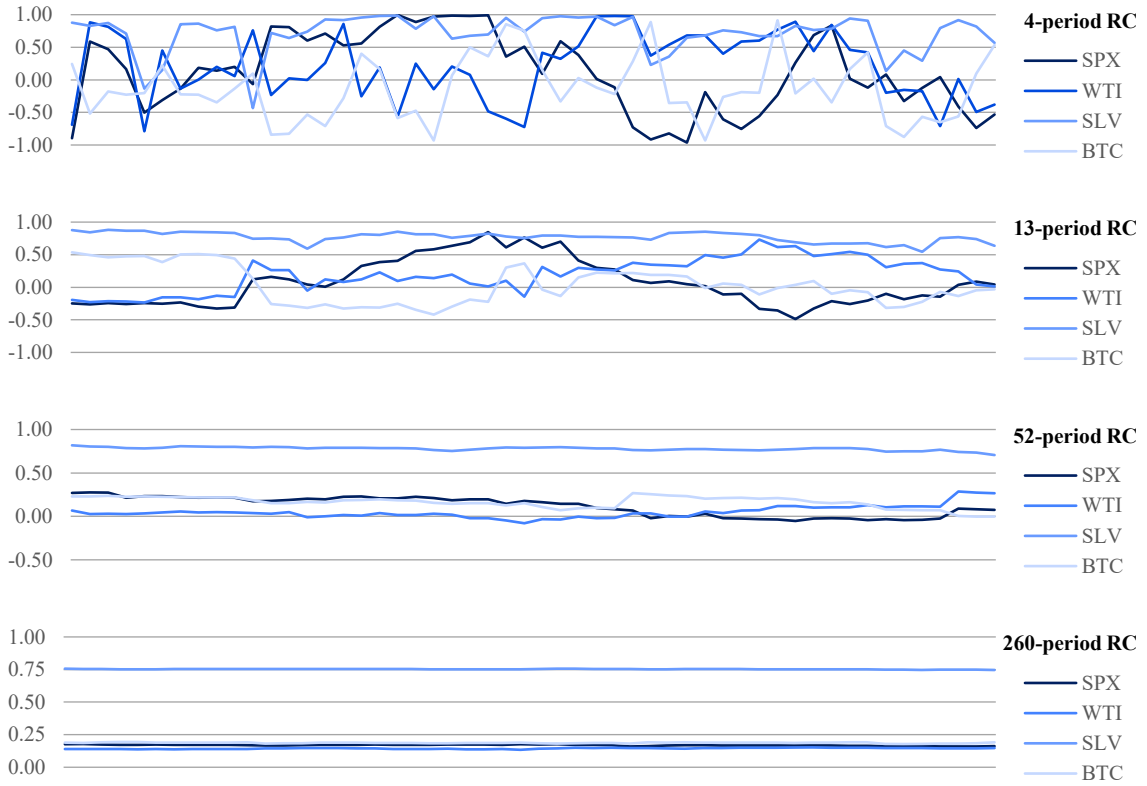




Source: own processing in MS Excel, for the detail of the source of data used check the bibliography.

With the 'typical' market assets being depicted on the graph no. 9, we observe relatively strong linear connections between gold and silver right from the highest frequency, right up to the lowest, which indicates strong linear connection among these variables. In some periods within higher frequencies, there is a persistent positive or negative correlation between gold and SPX, indicating, that their relationship is dynamic and at some time, gold moves in the opposite direction than stocks, other time they comove, and vice versa. On the 52-period graph, WTI is exhibiting almost no linear connection with gold, over the span of the last year, however, when we inspect the lowest frequency, we see slightly positive connection, although not sufficient for linearity assumption confirmation. With BTC, gold does not exhibit linear connection whatsoever.

Graph No. 9: Rolling correlations of various periods for the 'typical' market assets.

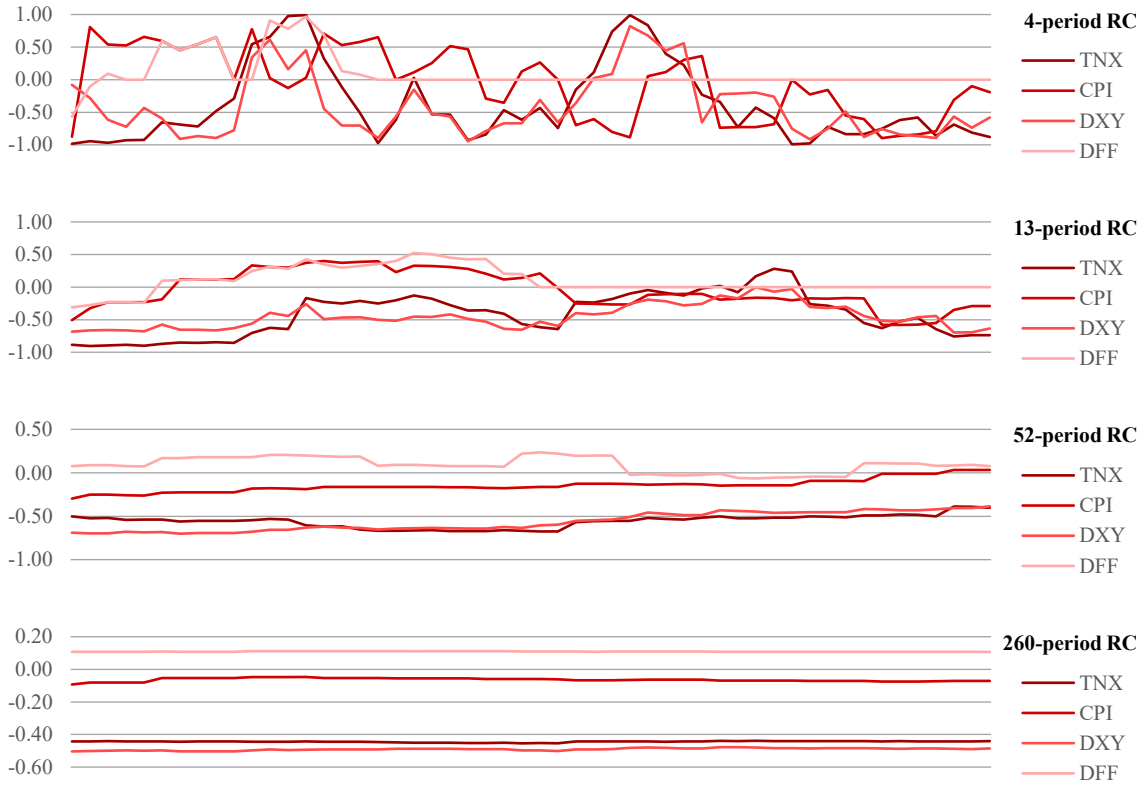


Source: own processing in MS Excel, for the detail of the source of data used check the bibliography.

With the macroeconomic measures depicted on the graph no. 10, gold has variable relationships in terms of linearity. With DFF, we observe there is hardly any correlation

present, which makes sense, because of the underlying DFF nature. With CPI, gold manifests weak negative correlation on the 52-period graph, at the beginning of the measured one-year period, which indicates, that there was a certain aspect of linearity, but consequently it faded, which is confirmed by the 260-period graph. However, with DXY and TNX, there is strong negative connection present. The relationship of gold and DXY is mostly negatively correlated, with few exceptions at the highest frequency, but as we look at broader time horizon, it becomes clear, that these variables are negatively interconnected in a linear fashion. The same applies also for the TNX, where it exhibits relatively obvious negative linear connection with gold. Additionally, the TNX and DXY seem to comove at strong connection among each other, which potentially implies the confirmation of the findings of the scholars, that these variables are interconnected, and that the strength of the USD is tightly knit with the yield on the 10-year US Treasury bond.

Graph No. 10: Rolling correlations of various periods for the macroeconomic measures.



Source: own processing in MS Excel, for the detail of the source of data used check the bibliography.

4.3 ARDL model construction

After the initial graphical and correlational analysis of the potential suitable variables for being emitters of economic shocks towards gold, we decided to utilize short-run ARDL model, in order to identify only the short-term dynamics between the elements. Initially, we performed a descriptive statistics inspection of the variables in question, which is described in the following table no. 2, and then decided to transform them by using the natural logarithm, because in this way we could 'normalize' the data and make them more symmetric and also to get closer to meet the criterion of the constant variance of the error, which are necessary for ARDL model stability and credibility. Natural logarithm transformations also allow for better interpretability of the data, because the resulting coefficients can be interpreted in terms of percentage change. In the table below we show the descriptive statistics of the researched variables before, and after the natural logarithmic transformations, while the variables which were not eligible for the transformation are differenced by color.

Table No. 2: The descriptive statistics of the variables before the transformation.

	Mean	Median	Standard error	Standard deviation	Maximum	Minimum	Range	Count
GOLD	1521.27	1406.13	13.91	309.73	2192.70	1055.40	1137.30	496
GVZ	15.90	15.65	0.19	4.25	48.98	8.88	40.10	496
SPX	3143.76	2887.78	41.27	919.04	5248.49	1851.86	3396.63	496
VIX	18.32	16.42	0.33	7.28	76.45	9.15	67.30	496
WTI	61.29	58.50	0.82	18.34	121.94	13.64	108.30	496
OVX	41.09	37.40	0.87	19.30	236.80	19.46	217.34	496
EPU US	115.22	90.43	3.81	84.96	553.21	20.08	533.13	496
GPR	118.42	106.50	2.48	55.22	523.52	23.36	500.16	496
TNX	2.33	2.26	0.04	0.94	4.95	0.54	4.41	496
SLV	17.97	16.58	0.16	3.48	26.15	11.21	14.94	496
DNSI	-0.01	0.02	0.01	0.18	0.33	-0.65	0.99	496
CPI	0.00	0.00	0.00	0.00	0.01	-0.01	0.02	496
DXY	97.26	96.80	0.22	4.93	113.32	85.15	28.17	496
BTC	15687.33	8670.18	778.24	17332.19	73083.50	178.10	72905.40	496
DFF	1.47	0.87	0.07	1.67	5.33	0.04	5.29	496
GGT	48.93	47.09	0.48	10.72	100.00	29.58	70.42	496
ANFCI	-0.43	-0.47	0.01	0.19	0.55	-0.83	1.38	496

Source: own processing in MS Excel, for the detail of the source of data used check the bibliography.

We observe there are nominally huge differences between the various values of the variables, therefore scaling them closer together makes also for a valid argument for the natural logarithmic transformation. After the transformation, the values are closer on a numerical scale than before, as is shown in the following table no. 3.

Table No. 3: The descriptive statistics of the variables after the transformation.

	Mean	Median	Standard error	Standard deviation	Maximum	Minimum	Range	Count
GOLD	7.31	7.25	0.01	0.20	7.69	6.96	0.73	496
GVZ	2.73	2.75	0.01	0.25	3.89	2.18	1.71	496
SPX	8.01	7.97	0.01	0.29	8.57	7.52	1.04	496
VIX	2.85	2.80	0.01	0.33	4.34	2.21	2.12	496
WTI	4.07	4.07	0.01	0.31	4.80	2.61	2.19	496
OVX	3.65	3.62	0.01	0.32	5.47	2.97	2.50	496
EPU US	4.55	4.50	0.03	0.60	6.32	3.00	3.32	496
GPR	4.68	4.67	0.02	0.42	6.26	3.15	3.11	496
TNX	0.75	0.81	0.02	0.46	1.60	-0.61	2.21	496
SLV	2.87	2.81	0.01	0.19	3.26	2.42	0.85	496
DNSI	-0.01	0.02	0.01	0.18	0.33	-0.65	0.99	496
CPI	0.0023	0.0023	0.0001	0.0029	0.0124	-0.0079	0.0203	496
DXY	4.58	4.57	0.00	0.05	4.73	4.44	0.29	496
BTC	8.64	9.07	0.08	1.77	11.20	5.18	6.02	496
DFF	-0.52	-0.14	0.07	1.53	1.67	-3.22	4.89	496
GGT	3.87	3.85	0.01	0.21	4.61	3.39	1.22	496
ANFCI	-0.43	-0.47	0.01	0.19	0.55	-0.83	1.38	496

Source: own processing in MS Excel, for the detail of the source of data used check the bibliography.

Furthermore, in order to construct ARDL model, a condition of stationarity at level I(0) or at first difference I(1) must be ensured, but no I(2) or higher order can be present. This flexible ability of the model to handle variables of different level type of stationarity is one of its strengths.[141] To assess whether our variables are stationary or nonstationary, we conducted two types of tests; Augmented Dickey-Fuller[142] (ADF) test and Phillips-Perron (PP) test[143]. Both tests are used to identify the presence of a unit root within the time series, with hypothesis H_0 stating that the time series contains unit root, therefore is nonstationary, which applies for both of these tests. The p-values below the significance level $\alpha = 0{,}05$ provides statistically significant evidence for the rejection of the null hypothesis, indicating stationarity at the level I(0). Otherwise, the failure to reject the null hypothesis suggests that non-stationarity is present within the data. The condition to accept stationarity was set that both tests must reject the null hypothesis. The tests were performed by utilizing Python, from where we obtained the following results of stationarity tests as is shown in the table no. 4.

[141] PESARAN, M. Hashem et al. Bounds testing approaches to the analysis of level relationships. In *Journal of applied econometrics* [online]. 2001, 16.3: 289-326.
[142] DICKEY, David A. and Wayne A. FULLER. Distribution of the estimators for autoregressive time series with a unit root. In *Journal of the American statistical association* [online]. 1979, 74.366a: 427-431.
[143] PHILLIPS, Peter C.B. and Pierre PERRON. Testing for a unit root in time series regression. In *Biometrika* [online]. 1988, 75.2: 335-346.

After the identification of nonstationary time series, we differenced them and conducted the stationarity tests again, now at the first difference level I(1) for the relevant time series. By differencing, we reduced the sample size by one observation, therefore we were now working with n = 495.

Table No. 4: The results of stationarity tests.

	Test type	Level I(0)			First difference I(1)		
		t-statistic	p-value	Stationarity	t-statistic	p-value	Stationarity
GOLD	ADF Test	-0.4832	0.8953	**FALSE**	-22.9831	0.0000	**TRUE**
	PP Test	-0.2515	0.9321	**FALSE**	-23.2469	0.0000	**TRUE**
GVZ	ADF Test	-4.0740	0.0011	**TRUE**	-	-	-
	PP Test	-4.3291	0.0004	**TRUE**	-	-	-
SPX	ADF Test	-0.4606	0.8995	**FALSE**	-21.8120	0.0000	**TRUE**
	PP Test	-0.1918	0.9395	**FALSE**	-22.3975	0.0000	**TRUE**
VIX	ADF Test	-4.5399	0.0002	**TRUE**	-	-	-
	PP Test	-5.6243	0.0000	**TRUE**	-	-	-
WTI	ADF Test	-2.7983	0.0585	**FALSE**	-8.0885	0.0000	**TRUE**
	PP Test	-2.6035	0.0923	**FALSE**	-20.5248	0.0000	**TRUE**
OVX	ADF Test	-4.1456	0.0008	**TRUE**	-	-	-
	PP Test	-4.7644	0.0001	**TRUE**	-	-	-
EPU US	ADF Test	-2.5612	0.1013	**FALSE**	-7.2890	0.0000	**TRUE**
	PP Test	-15.6513	0.0000	**TRUE**	-68.9583	0.0000	**TRUE**
GPR	ADF Test	-4.0795	0.0010	**TRUE**	-	-	-
	PP Test	-19.0056	0.0000	**TRUE**	-	-	-
TNX	ADF Test	-1.2588	0.6478	**FALSE**	-9.4781	0.0000	**TRUE**
	PP Test	-1.3792	0.5922	**FALSE**	-24.4590	0.0000	**TRUE**
SLV	ADF Test	-2.1356	0.2304	**FALSE**	-12.8186	0.0000	**TRUE**
	PP Test	-1.9110	0.3269	**FALSE**	-23.7520	0.0000	**TRUE**
DNSI	ADF Test	-3.4225	0.0102	**TRUE**	-	-	-
	PP Test	-3.0602	0.0296	**TRUE**	-	-	-
CPI	ADF Test	-3.7236	0.0038	**TRUE**	-	-	-
	PP Test	-4.8216	0.0000	**TRUE**	-	-	-
DXY	ADF Test	-2.6223	0.0885	**FALSE**	-17.2055	0.0000	**TRUE**
	PP Test	-2.6910	0.0756	**FALSE**	-21.8488	0.0000	**TRUE**
BTC	ADF Test	-0.7587	0.8310	**FALSE**	-14.7731	0.0000	**TRUE**
	PP Test	-0.8523	0.8033	**FALSE**	-22.1777	0.0000	**TRUE**
DFF	ADF Test	-1.2775	0.6394	**FALSE**	-13.1321	0.0000	**TRUE**
	PP Test	-1.3677	0.5977	**FALSE**	-21.7703	0.0000	**TRUE**
GGT	ADF Test	-4.8868	0.0000	**TRUE**	-	-	-
	PP Test	-4.4821	0.0002	**TRUE**	-	-	-
ANFCI	ADF Test	-2.7841	0.0606	**FALSE**	-6.7658	0.0000	**TRUE**
	PP Test	-3.2122	0.0193	**TRUE**	-4.2509	0.0005	**TRUE**

Source: own processing in MS Excel, based on the results from Python, for the detail of the source of data used check the bibliography.

As it is shown in the table no. 4 above, some variables needed to be differenced in order to be eligible for ARDL model inclusion. This confirms our earlier considerations for the need of differencing. Traditionally, volatility measures did not exhibit non-stationarity at the level I(0), together with uncertainty measures GPR, GGT and DNSI, with CPI included.

4.3.1 Optimal ARDL model selection

As we distinguished our variables within four categories, we proceeded to test their eligibility for our particular short-run ARDL model structure, in order to find the most robust combination of them, for obtaining reliable results. To estimate the short-term dynamics of the relationships between the variables, we utilized short-run ARDL models for each of the respective categories and compared them. Initially, it was necessary to find the optimal lag structure for the short-run ARDL model specification, which was conducted by utilizing Akaike Information Criterion[144] (AIC), upon which we selected the optimal lag structure for each of the variables. In the following table below, optimal lags for short-run ARDL models are depicted, whereas the constraining criterion of maximum lag, to achieve the full potential of optimal lag selection, was set to 25. The results are depicted in the table no. 5 below.

Table No. 5: Optimal lag selection by AIC.

	Uncertainty model		**Volatility model**		**'Typical' assets model**		**Macroeconomic model**	
	Variable	**AIC**	**Variable**	**AIC**	**Variable**	**AIC**	**Variable**	**AIC**
Dependent Variable	GOLD	1	GOLD	1	GOLD	1	GOLD	1
Independent Variables	EPU US	20	GVZ	4	SPX	1	TNX	4
	GPR	8	VIX	2	WTI	10	DXY	2
	GGT	1	OVX	2	SLV	4	DFF	2
	ANFCI	21			BTC	2	CPI	10

Source: own processing in MS Excel, based on the results from RStudio, for the detail of the source of data used check the bibliography.

After the optimal lag criteria specification, we constructed four default short-run ARDL models based on the four categories. In the following table no. 6, we summarize the results, whereas our primary focus was on the adjusted R^2 value. The adjusted coefficient of determination should not be the only parameter upon which the decisions for the optimal modelling would be made, but in our case, we aimed to find the optimal short-run ARDL

[144] AKAIKE, Hirotogu. Information theory and an extension of the maximum likelihood principle. In *Selected papers of Hirotugu Akaike. New York, NY: Springer New York* [online]. 1998. p. 199-213.

model, which would both provide consistent and robust result, and also explain the relationships between the dependent and independent variables well. The adjusted coefficient of determination, in addition to quantifying how well is the variation of the dependent variable explained by the independent variables, penalizes the overfitting of the model, by decreasing its value, if unnecessary variables are added to the model. Therefore, we were continuously disregarding the models and the variables, which were lowering the adjusted R^2. The reasons for adjusted R^2 being low are various. First of all, model misspecification can be a factor, because of the absence of relevant predictors, respectively the omitted variable bias, adjusted coefficient of determination can have low value. The next reason might be weak effect of the independent variable on the dependent variable. And last, but not least, a nonlinear relationship might be present among the variables, which short-run ARDL model is unable to capture.

Table No. 6: Adjusted R^2 for each type of categorical model.

Adjusted R2	Uncertainty model		Volatility model		'Typical' assets model		Macroeconomic model	
	model1A	0.0607	model2A	0.0089	model3A	0.5742	model4A	0.3327

Source: own processing in MS Excel, based on the results from RStudio, for the detail of the source of data used check the bibliography.

From the adjusted R^2 we concluded that model with 'typical' assets explains the variability of gold the best, however, we decided to further combine the models together, in order to abstain from omitted variable bias, and include ideal number of necessary variables from each group. After running additional fourteen short-run ARDL models, we found combination of variables, which was having the highest adjusted coefficient of determination, at the level of 0.66. However, this model contained 11 variables, which could lead to overfitting. This model was called model5E6 and consisted of GOLD as a dependent variable and TNX, DXY, SPX, WTI, SLV, GVZ, OVX, GPR, GGT and ANFCI as the independent variables with their relevant lags, except for WTI, where the lag structure has been altered from 10 to 6, in order to extrapolate from unnecessary lag proportion. Apart from the stationarity requirements, short-run ARDL model needs to fulfill other conditions, mainly no autocorrelation of the residuals, no heteroskedasticity of the residuals and the normality of the residuals. After we conducted the first test of autocorrelation for the model5E6, we found it to be present, so we decided to further exclude variables, namely ANFCI, which was having long lag string, and OVX. This led to the model5E6A, where we obtained adjusted R^2 at 0.6480 level, however, this model suffered from heteroskedasticity and heavily from multicollinearity. After we removed GVZ in order to estimate model5E6B,

the multicollinearity issue seemed more in control, although it was still present, especially in the GGT element, while heteroskedasticity remained a general problem. Moreover, GGT element did not yield any statistically significant coefficients within the model, so we decided to remove it from the regression. Afterwards, model5E6C was introduced, which consisted of dependent variable GOLD and six independent variables, namely TNX, DXY, SPX, WTI, SLV and GPR. This model yielded the most satisfactory results and the details are disclosed in the following subsegment.

4.3.2 The best suitable model

A short-run ARDL, which is a version of ARDL model with the excluded long-term element, must abide by the rules by which the ARDL model is constructed and deemed eligible for the interpretation. At the beginning, we controlled for the stationarity, and adjusted our variables accordingly. Consequently, we assembled our model5E6C, which consists of GOLD being the dependent variable and TNX, DXY, SPX, WTI, SLV, GPR being the independent variables, with their respective lags, except for WTI, which was kept at 6.

Initially, we tested the model for the presence of heteroskedasticity in the residuals, by utilizing Breusch-Pagan test[145], from which we obtained a BP – test statistic with the value of 45.195, with 32 degrees of freedom, because of the number of regressors in the model and the p-value of 0.0610, by which we fail to reject the null hypothesis of homoskedasticity, because of the assumed significance level $\alpha = 0.05$. Therefore, homoskedasticity is assumed, based on the results from the test.

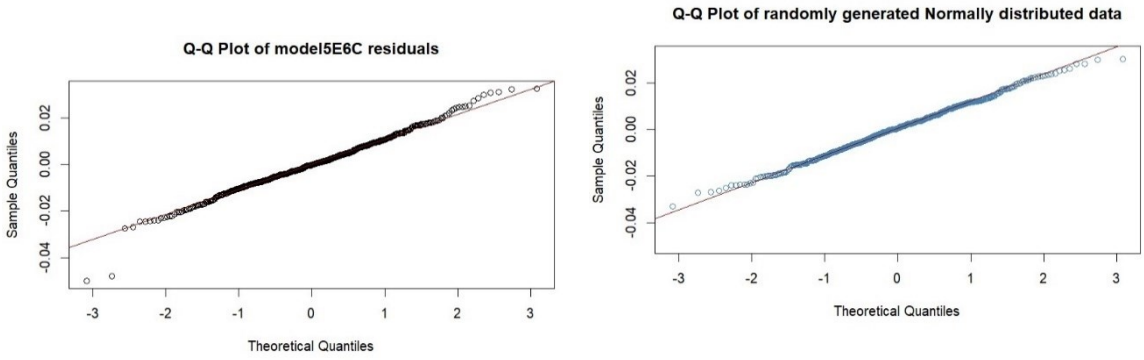
Then we proceeded to test for the autocorrelation of the residuals, up to the 8th lag, in order to comprehensively fulfill the necessary requirements for estimating the short-run dynamics from the ARDL model. For this purpose, we used Breusch-Godfrey test[146] for autocorrelation. The null hypothesis states that there is no serial correlation up to the specified order, against the alternative hypothesis which states that there is a serial correlation. From this test we obtained a LM – test statistic with the value of 7.8544, with 8 degrees of freedom and p-value of 0.4478, due to which we failed to reject the null

[145] BREUSCH, Trevor S. and Adrian R. PAGAN. A simple test for heteroscedasticity and random coefficient variation. In *Econometrica: Journal of the econometric society* [online]. 1979, 1287-1294.
[146] BREUSCH, Trevor .S. and L.G. GODFREY. Misspecification Tests and Their Uses in Econometrics. In *Journal of Statistical Planning and Inference* [online]. 1978, 49, 241-260.

hypothesis and concluded that there is no autocorrelation among the residuals up to the 8th lag, based on the significance level $\alpha = 0.05$.

Furthermore, we conducted the normality test of the residuals, by using Anderson-Darling test[147] for normality and by visually plotting the residuals on Q-Q plots, compared to randomly generated numbers with the same statistical properties in terms of mean and variance as the residuals. This can be seen on the graph no. 11. For the Anderson-Darling test the null hypothesis states that the data is normally distributed, at the significance level of $\alpha = 0.05$. We obtained a p-value of 0.1318 and the Anderson-Darling test statistic A = 0.5787, which means that we failed to reject the null hypothesis based on the lack of statistical evidence, and therefore concluded the normality of the residuals. Additionally, on the graphs depicted below, we observed that there exist deviations from the normality in two of the model's residuals, but generally, the distribution is well aligned along the Q-Q line, so we concluded normality also from the visual inspection.

Graph No. 11: Q-Q plots for the visual normality tests of the model5E6C residuals.



Source: own processing in RStudio, for the detail of the source of data used check the bibliography.

Next, we inspected for the multicollinearity, using Variance Inflation Factor (VIF) and derived the Tolerance from it. Even though ARDL model handles multicollinearity better than OLS alone, for the sake of stability it should be inspected and addressed accordingly. In the previous versions of the model, we encountered several issues with high multicollinearity, and we were forced to discard some variables in order to improve the overall functionality of our short-run ARDL model. In the table no. 7 depicted below we displayed the results, while our evaluation criterion was set out to accept values for VIF under <5 as a range of low multicollinearity, while for the tolerance the lower bound was set

[147] ANDERSON, T. W. and D.A. DARLING. "Asymptotic theory of certain "goodness-of-fit" criteria based on stochastic processes". In *Annals of Mathematical Statistics* [online]. 1952, 23 (2): 193–212.

out to 0.2, as the Tolerance is computed by inversing the VIF. The results suggest no unacceptable levels of multicollinearity at the significance level of $\alpha = 0.05$.

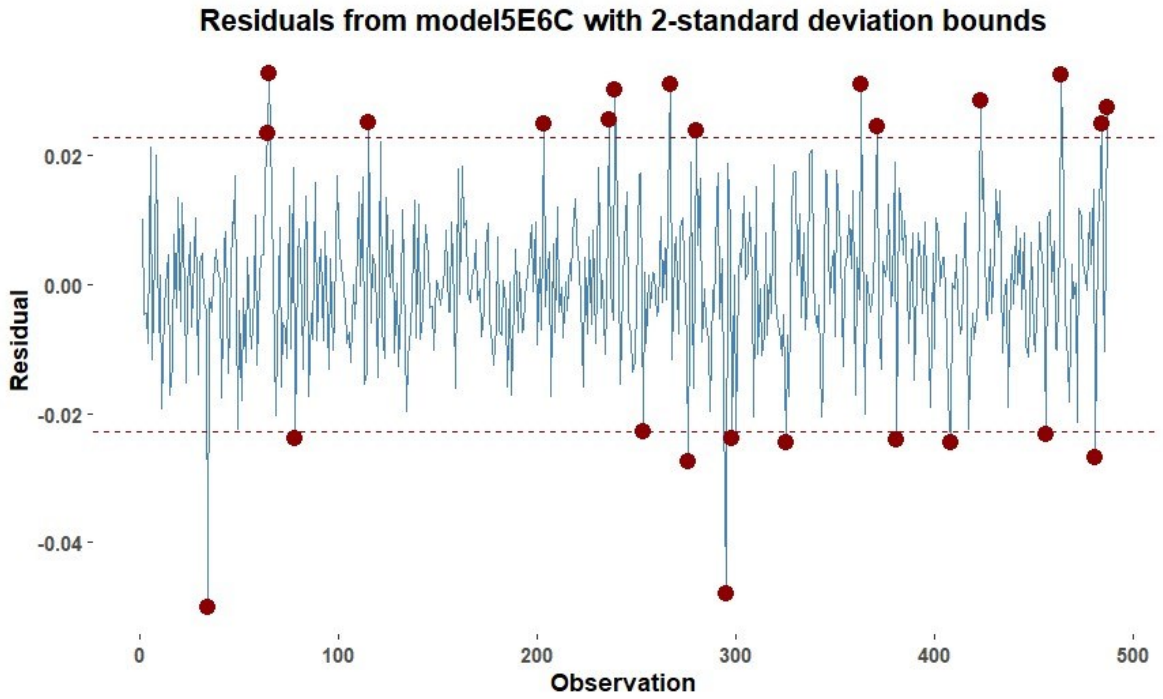
Table No. 7: Multicollinearity detection for model5E6C.

Variance inflation factor				Tolerance			
L(GOLD, 1)	2.9741	L(WTI, 5)	1.1789	L(GOLD, 1)	0.3362	L(WTI, 5)	0.8482
TNX	1.4723	L(WTI, 6)	1.1707	TNX	0.6792	L(WTI, 6)	0.8542
L(TNX, 1)	1.6117	SLV	1.7722	L(TNX, 1)	0.6205	SLV	0.5643
L(TNX, 2)	1.5210	L(SLV, 1)	3.0824	L(TNX, 2)	0.6574	L(SLV, 1)	0.3244
L(TNX, 3)	1.4908	L(SLV, 2)	1.6595	L(TNX, 3)	0.6708	L(SLV, 2)	0.6026
L(TNX, 4)	1.4749	L(SLV, 3)	1.4229	L(TNX, 4)	0.6780	L(SLV, 3)	0.7028
DXY	1.4429	L(SLV, 4)	1.4350	DXY	0.6930	L(SLV, 4)	0.6969
L(DXY, 1)	1.4731	GPR	1.4574	L(DXY, 1)	0.6789	GPR	0.6862
L(DXY, 2)	1.4068	L(GPR, 1)	1.5368	L(DXY, 2)	0.7108	L(GPR, 1)	0.6507
SPX	1.4543	L(GPR, 2)	1.5317	SPX	0.6876	L(GPR, 2)	0.6529
L(SPX, 1)	1.5383	L(GPR, 3)	1.5105	L(SPX, 1)	0.6501	L(GPR, 3)	0.6621
WTI	1.4630	L(GPR, 4)	1.5488	WTI	0.6835	L(GPR, 4)	0.6457
L(WTI, 1)	1.4440	L(GPR, 5)	1.5367	L(WTI, 1)	0.6925	L(GPR, 5)	0.6507
L(WTI, 2)	1.3504	L(GPR, 6)	1.5106	L(WTI, 2)	0.7405	L(GPR, 6)	0.6620
L(WTI, 3)	1.3428	L(GPR, 7)	1.5020	L(WTI, 3)	0.7447	L(GPR, 7)	0.6658
L(WTI, 4)	1.3622	L(GPR, 8)	1.5000	L(WTI, 4)	0.7341	L(GPR, 8)	0.6667

Source: own processing in MS Excel, based on the results from RStudio, for the detail of the source of data used check the bibliography.

Finally, we assessed the model's stability by performing M-Fluctuation test to assess the parameters' stability and also plotting the model's residuals with the set boundary of 2 standard deviations, in order to identify outliers and assess the overall stability of the model. The M-Fluctuation Test is a statistical method used to assess the stability of model parameters over time, detecting shifts or inconsistencies. From the test we obtained f(efp) – test statistic of 1.378 with the p-value being 0.7799. Therefore, we conclude that there is no statistically significant evidence to reject the null hypothesis of no parameter drift nor differential item functioning at the significance level of $\alpha = 0.05$. On the graph no. 12 depicted below, we observed the plot of residuals with their respective upper and lower boundaries set to be 2 standard deviations from the mean, to represent the 95 % confidence interval. We found that out of the total $n = 487$ residuals, 25 lie outside the boundaries, which is 5.13%. This is very close to the significance of level of $\alpha = 0.05$, suggesting substantial model stability.

Graph No. 12: Residual plot with the 2-standard deviation bounds.



Source: own processing in RStudio, for the detail of the source of data used check the bibliography.

5 Discussion

In this section we present and interpret the results of our short-run ARDL model estimation, together with the evaluation of our hypotheses. A gradual process of categorical model selection based on the adjusted coefficient of determination resulted into selection of the optimal model configuration in terms of highest adjusted R^2. However, we must have had considered other factors which determine the quality of model, and we did not focus solely on the adjusted coefficient of determination. Afterwards, we applied diagnostic metrics tests for effects such as heteroskedasticity, autocorrelation, normality, multicollinearity, and stability check to further refine our variable selection for the model. Consequently, we attained a version of our short-run ARDL which fulfills all the necessary requirements, for which we present the results.

5.1 Interpretation of the short-run ARDL model results

In the following table we provide comprehensive results from the ARDL regression. As we can see, the basic characteristics of the model meet the criteria for being robust and efficient in its estimates. The F-statistic is high at the level of 27.9, when compared to the critical value of F-statistic with the same configuration, which equals 1.4692, at the significance level $\alpha = 0.05$ and $\alpha = 0.01$. The p-value at 2.20E-16 indicates that we can reject the null hypothesis of all regression coefficients being zero, because there is no significant statistical evidence to suggest otherwise. Furthermore, the model explains around 63.92 % of the variation in the price of gold by the included regressors, based on the result of adjusted R^2. The residuals' standard error is 0.0118, which is fairly low and represents the average distance that the observed values fall from the regression line. We note that every variable within the model is transformed by natural logarithm and all, but GPR ale differenced beforehand. Moreover, every variable within the model is marked by statistical significance of various degrees and we provide the interpretation below the table no. 8, which provides detailed evidence.

Table No. 8: short-run ARDL regression model5E6C results.

Start:	9	**End:**	495		
Residuals:					
Min	**1Q**	**Median**	**3Q**	**Max**	
-0.050077	-0.007108	-0.000130	0.007437	0.032640	
Coefficients:					

	Estimate	Std. Error	t-value	Pr(>|t|)	
(Intercept)	-0.009032	0.009493	-0.9510	0.341888	
L(GOLD,1)	**-0.120621**	**0.047019**	**-2.5650**	**0.010626**	*
TNX	**-0.064681**	**0.010576**	**-6.1160**	**0.000000**	***
L(TNX,1)	-0.014959	0.011058	-1.3530	0.176799	
L(TNX,2)	**-0.038711**	**0.010744**	**-3.6030**	**0.000349**	***
L(TNX,3)	0.012557	0.010638	1.1800	0.238443	
L(TNX,4)	0.002716	0.010585	0.2570	0.797592	
DXY	**-0.287228**	**0.067209**	**-4.2740**	**0.000023**	***
L(DXY,1)	**-0.200233**	**0.067964**	**-2.9460**	**0.003383**	**
L(DXY,2)	-0.006877	0.066440	-0.1040	0.917607	
SPX	**-0.148463**	**0.028671**	**-5.1780**	**0.000000**	***
L(SPX,1)	-0.011258	0.029482	-0.3820	0.702737	
WTI	0.004379	0.009751	0.4490	0.653619	
L(WTI,1)	-0.008894	0.009688	-0.9180	0.359064	
L(WTI,2)	0.000923	0.009367	0.0990	0.921537	
L(WTI,3)	**-0.016135**	**0.009340**	**-1.7280**	**0.084756**	.
L(WTI,4)	0.004087	0.009403	0.4350	0.664046	
L(WTI,5)	-0.003916	0.008747	-0.4480	0.654582	
L(WTI,6)	0.005036	0.008717	0.5780	0.563764	
SLV	**0.329394**	**0.018368**	**17.9330**	**0.000000**	***
L(SLV,1)	**0.044598**	**0.024234**	**1.8400**	**0.066375**	.
L(SLV,2)	0.011656	0.017777	0.6560	0.512378	
L(SLV,3)	**0.040616**	**0.016465**	**2.4670**	**0.013999**	*
L(SLV,4)	-0.012967	0.016453	-0.7880	0.431056	
GPR	**0.004508**	**0.001524**	**2.9590**	**0.003249**	**
L(GPR,1)	-0.000564	0.001565	-0.3600	0.718883	
L(GPR,2)	-0.000730	0.001562	-0.4670	0.640649	
L(GPR,3)	0.001381	0.001549	0.8920	0.373008	
L(GPR,4)	-0.001375	0.001569	-0.8770	0.381162	
L(GPR,5)	0.001573	0.001564	1.0060	0.315022	
L(GPR,6)	0.000602	0.001553	0.3880	0.698330	
L(GPR,7)	0.000410	0.001549	0.2650	0.791432	
L(GPR,8)	**-0.003522**	**0.001547**	**-2.2760**	**0.023307**	*
Significance codes:		0.001 - ***	0.01 - **	0.05 - *	0.1 - .
Residual standard error:		0.0118	on 454 DF		
Mean of residuals:		2.6694E-11			
Multiple R-squared:		0.6629			
Adjusted R-squared:		0.6392			
F-statistic:		27.9	on 32 and 454 DF, critical value: 1.4692		
p-value:		2.20E-16			

Source: own processing in MS Excel based on the results from RStudio.

The first statistically significant regressor is the lagged value of the dependent variable itself, more specifically GOLD, from the past week, because of the weekly

frequency of our data. The coefficient is statistically significant at $\alpha = 0.05$ level and with the value of -0.1206. Since all of our variables are transformed by using natural logarithms, we can interpret the coefficients as the percentual unit changes. Furthermore, when interpreting the differenced variables, we have to bear in mind that the differences represent the changes from time n-1 to time n. Therefore, the interpretation of the coefficient of -0.1206 for lag 1, means that the model estimates, on average, that when there is 1 % change in the growth rate of the gold from week -2 to week -1, it results in -0.1206 % change in the gold's growth rate from week -1 to week 0. In other words, when there is a 1 % positive change in the growth rate of gold from week -2 to week -1, it results into gold's negative change in the growth rate from week-1 to week 0, respectively to the present week.

TNX is statistically significant in its relationship to gold's spot price in the present period and in the 2nd lag, with the coefficients being -0.0646 and -0.0387, respectively. This constitutes statistically significant linear negative relationship between the yield on a 10-year US Treasury Bond and the gold. The 1 % change in the growth rate of TNX from week -3 to week -2 results in negative change in growth rate of the price of gold from week -1 to week 0 at the estimated -0.0387 % change. Additionally, the 1 % change in the TNX's growth rate from week -1 to week 0 results into -0.0646 % change in the growth rate of the gold's price within the same time period. Because of the nature of logarithmic changes, they allow for additive effects, and allow us for the following assumption. The total cumulative influence of a 1% change in the growth rate of TNX on the growth rate of gold's spot price is not exclusively caused by its present influence, but also incorporates the effects from its lags. Specifically, the cumulative effect includes the influence from the present week and the 2nd lag. Therefore, the total cumulative impact of a 1% change in the growth rate of TNX on the growth rate of gold's spot price amounts to a -0.1033% change over the specified time period. This allows us to conclude an inverse relationship between the variables.

Besides the strong indirect linear connection between gold prices and USD, trough TNX, we observed strong linear connection with the US dollar itself. DXY is statistically significant in its relationship with gold at the present and 1st lag periods. The statistically most significant influence is exhibited at the present period, with the coefficient value of the negative -0.2872, at the significance level of $\alpha = 0.001$, while for the 1st lag, we observe the coefficient value of negative -0.2002, at the significance level of $\alpha = 0.01$. Based on these results, we can interpret that the model estimates, on average, that 1 % change in the growth rate of DXY from week -2 to week -1 results in the -0.2002 % change in the growth rate of GOLD from week -1 to the present week. Similarly, the response is stronger at the more

recent 1 % change in the growth rate of DXY from week -1 to week 0 in a sense, that this is supposed to result, on average, into -0.2872 % change in growth rate of GOLD from week -1 to week 0. Based on the assumption of the additivity of natural logarithmic changes, considering both the current week and its 1st lag, a 1% change in the growth rate of DXY over two weeks (from week -2 to the present week) results in a negative -0.4874% change in the growth rate of gold. Also here, we confirm, that based on the estimates of our model, there exists quite strong inverse relationship between gold and US dollar.

Traditionally, as the gold is considered to be a safe haven and a hedge for the US stock market particularly, our model confirms this relationship at the statistically significant level of $\alpha = 0.001$. The estimated coefficient is -0.1485 for the present period, which can be understood as a 1 % change in the growth rate of SPX from the previous week, based on the estimation results simultaneously into negative -0.1485 % change in the growth rate of the price of gold for the same time period. Conversely, this means that when the stocks decline, by inverse, gold rises.

In this particular model and its configuration, we were able to also detect the influence of the change in the growth rate of the WTI at the 3rd lag, with the negative coefficient of -0.0161, although at the weaker significance level of $\alpha = 0.1$. This means that the 1 % change in the growth rate of WTI from week -4 to week -3 results into -0.0161 % change in the growth rate of the spot price of gold from week -1 to week 0.

Strong linear relationship is observed between the lagged changes in the growth rate silver values and the changes in the growth rate of the price of gold. SLV coefficients for the present, 1st and 3rd lag were 0.3294, 0.0446 and 0.0406, with their respective significance levels of $\alpha = 0.001$, $\alpha = 0.1$ and $\alpha = 0.05$. These estimates indicate that on average a 1 % change in the growth rate of SLV from week -4 to week -3 results into 0.0406 % change in the growth rate of GOLD from past to present week. Moreover, 1 % change in the growth rate of SLV from week -2 to week -1 results into 0.0446 % change in the growth rate of gold from week to week. Strongest response is estimated in the change of the growth rate of SLV from week -1 to the present week, where the 1 % change results into 0.3294 % change in the growth rate of GOLD at the same time frame. Cumulatively, the effect of 1% SLV changes in the growth rate over the period of the past month, result, on average, into 0.4146 % change in the growth rate of GOLD. This underlines the strong nexus between the assets, however from this perspective we only examine the effect of silver on gold, but not the effect of gold on silver, and therefore we cannot conclude which one is more significant.

Finally, the last statistically significant variable was GPR, with the coefficient of 0.0045 from the current period with significance level of $\alpha = 0.01$ and the coefficient of negative -0.0035 from the 8^{th} lag, being significant at the $\alpha = 0.05$ level. Because the GPR was not differenced, we interpret the results as the 1 % change in the GPR at the 8^{th} lag has a negative effect of -0.0035 % on the change in the growth rate of GOLD from week -1 to week 0. Moreover, the 1 % change in the GPR in the current week creates 0.0045 % influence on the change in the growth rate of GOLD from week -1 to week 0. This can be interpreted that based on the estimates, the current growth in geopolitical risk, might positively impacts the current price of gold, however, on average, after two months, the growth of the GPR exerts negative influence on the price of gold. This could imply that after the initial shock from GPR calms down, gold is no longer perceived as a hedge against the geopolitical risk and is sold.

It is important to state, that within the interpretation we worked with the assumptions made on the principles of properties of natural logarithm changes, and also on the principle of ceteris paribus, which is paramount for the linear, OLS-based regression. Therefore, the estimated effect of each variable is computed as the other variables are being held constant, and even if there is a potential to interpret the results cumulatively, it cannot be done within this framework.

Interestingly enough, when correlational analysis and the results of our modeling are compared, we can clearly see, that in general, only correlationally stronger relationships ended up being evaluated in the model. Even though this is inherently the result of our selection criteria and process, but the process stemmed from the inbuild capacity of the model to evaluate only the linear relationships. For the variables which were excluded, based on the low adjusted coefficient of determination, we also observed correlations around zero. This yields potential to inspect the effects of these variables in the nonlinear setting in order to estimate their potential connections with the price of gold.

5.2 Potential limitations of the model

The ARDL model is a linear regression model based on the OLS estimation. Naturally, this can pose some limitations in the model's estimation of the relationships between the variables. Most importantly, the short run version of ARDL cannot capture the long-term connections between the variables, as the full version of ARDL model can, given the predisposition that they exist. Conversely, the model is linear, and cannot capture or explain nonlinear relationships between the variables. This means that even though many of

the examined independent variables exhibited no connection to the dependent variable, but this is true only in the linear sense. Models which can handle nonlinearity of the relationships between the variables can potentially yield different results, if in fact, such an underlying link exists. The model also cannot capture the causal effect between the variables, henceforth we must always assess the effects within the framework of linear estimates, which holds on average, which is rather simplification of the true underlying relationships which might be present. Moreover, we also cannot estimate the cumulative effect of independent variables on the dependent variable, because of the ceteris paribus principle.

5.3 Evaluation of the established hypotheses

The hypotheses were established in order to look for the particular specifics within the relationship of examined variables and gold's price. In this subsegment we provide the interpretation of results in terms of answers to our hypotheses.

H_1: *At least one of the variables' group is represented in the model by one or more determinants with statistically significant and robust results.*

We conclude that we cannot reject this hypothesis because we do not have sufficient statistical evidence. Quite the opposite, we found statistically significant evidence in our model's result, which suggests that determinants from uncertainty measures, 'typical' market assets and macroeconomic groups are represented in the valid output of the model. The volatility measures group is not represented in our robust model but can be a potential subject to nonlinear modeling. Furthermore, based on our estimates, we can confirm the findings of other scholars and authors, that there exists complex and intricate network among gold's price determinants. Additionally, we obtained estimates, which can measure the magnitude and the time dimension of economic shock impact coming from the examined variables towards gold. Therefore, we successfully estimated the impact of economic shocks on the price of gold.

H_2: *Search of the word "gold" on the Google has influence on the gold's price.*

We were not able to obtain sufficient statistical evidence to support this hypothesis, therefore we reject it. When the models were constructed, we included variable GGT, which measures the occurrence of the word "gold", in multiple of them. Either we obtained insignificant results straight from the beginning, or after model diagnostics we concluded that the particular model is not eligible for interpretation because of its failure to meet the proper evaluation criteria. This could be possibly due to the nonlinearity of the relationship

between the variables, or that in the particular model configuration the influence of GGT on gold's price is dimmed by the other variables. However, we propose a suggestion for the further research, which could examine whether GGT has impact on GOLD in nonlinear settings, or whether it is vice versa. Possible explanation might be offered that economic shocks which manifest also into people's behavior and consequently searches for safe haven of any sorts to protect themselves from the negative effects, might result in delayed search for "gold" on the Google search, at the time, when more educated market participants already elevated the assets price, because of their informational edge.

H_3: *Aggregate metrics reflecting the economic and financial conditions have influence on the price of gold.*

We did not find sufficient and statistically significant evidence for the acceptance of this hypothesis; therefore, we reject it. However, this does not imply that there is no real connection between the economic and financial conditions measures. Once again, the relationship between these variables and gold seems to be of nonlinear character, based on the results of our data frame and estimates. Gold did respond to changes in geopolitical risk at statistically significant levels within our model's configuration, which implies that there is a certain connection between shocks stemming from geopolitical instability and gold. Geopolitical instability consequently leads to economic instability, to which, by this logic, gold indirectly responds.

Conclusion

As the result of our research, we conclude that a short-run ARDL model specification is particularly useful for the inquiry of linear relationships among gold and its determinants with the inclusion of the time effect inquiry. Based on our selection criteria, we selected linearly responsive determinants, such as the 10-year US Treasury bond yield, US Dollar Index, S&P 500 Index, West Texas Intermediate crude oil, silver, and geopolitical risk, in order to robustly estimate the influences exerted upon gold.

Our findings confirm the notions established by the academic research, especially the negative relationship between gold and its immediate previous value, potentially indicating partial mean reversion, gold and TNX, gold and DXY, gold and SPX, gold and WTI, and positive relationship between gold and SLV, and mixed relationship between gold and GPR. Furthermore, the added value of our master thesis lies in the results of our hypotheses, whereas we confirm, that uncertainty, 'traditional' market assets and macroeconomic measures affect the gold's price in linear and statistically significant way. With the volatility measures, we were not successful to quantify the effects on the price of gold in the linear setting. Moreover, we conclude, that the search of the word "gold" on the Google can be potentially connected to gold's price in nonlinear fashion, as well as the influence of the aggregate metrics reflecting the economic and financial conditions. This provides potential basis for the future research.

By our model estimates, we successfully measured the average response of gold to the various economic shocks impacting its price at various points in time. Additionally, the results of our correlational analysis imply, which assets are eligible for usage in portfolio diversification and what to potentially expect from their ever-evolving behavior in the broad spectrum of market conditions.

Gold still represents viable asset for the portfolio diversification, and if used correctly, it can be successfully utilized as a hedge and a safe haven for the unexpected market events resulting in turmoil and general downturn, even after various possible structural changes within the market, due to its fundamental and behavioral connections to humanity.

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