PRICE DYNAMICS OF GOLD AND SILVER IN THE PERIOD 2015-2023

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Abstract: The aim of this paper was to map the price development of selected metal commodities - gold and silver from 1 January 2015 to 1 January 2023, to determine whether the COVID-19 pandemic had an impact on their price development and whether there is a linear relationship between the prices of these commodities. The validity of the correlation between the prices of gold and silver was examined using correlation analysis. Granger causality confirmed a statistically significant relationship between past gold and silver prices, indicating their mutual predictive value for future prices. The price data was obtained by content analysis and evaluated by graphical analysis. During the period under review, the price of both commodities increased, and the curves of both commodities followed a similar pattern. The gold price evolved from the original value of CZK 877.19/g to the price quoted on 1 January 2023, which was CZK 1,327/g. The price of silver also saw a price development, from CZK 11.64/g to CZK 17.43/g. From an investment point of view, the COVID-19 pandemic had a positive effect on both commodities, as prices increased significantly, especially for gold, which can serve as an investment metal in times of economic crises. The biggest limitation of the work were events such as the COVID-19 and the war in Ukraine, which influenced the price development of both commodities and thus could have affected the results of the research.

Keywords: Gold, silver, correlation analysis, price development, COVID-19 pandemic.

1 Introduction

Commodities have long been considered an outsider in the investment world, often for a good reason. Unlike shares, commodities do not offer the so-called market´s beta. In contrast, they represent a set of unique price returns reflecting the underlying dynamics of supply and demand for tangible assets that serve as a building block of the global economy [1]. The literature describes a significant relationship between commodity prices and their futures and macroeconomic variables, which indicates the important role commodities play in the real economy [2]. Commodity futures contracts originated as a form of agricultural insurance and were primarily used for the stabilization of commodity prices [3]. Generally, the actual price of globally traded commodities is determined by supply and demand. One of the major factors determining the actual price of commodities is changes in demand for commodities associated with unexpected fluctuations in global real economic activity [4]. Given that the supply of commodities is vital to modern society, fluctuations in commodity prices can significantly affect the functioning and sustainable development of macroeconomy, manufacturing activities, and people´s safety and well-being. The commodity market also plays a key role in international industrial chain and sustainable development [5]. Price jumps in commodity markets are rare and extreme events occur less often than in stock markets. However, the correlation of jumps between commodities can be high depending on the commodity sectors. Energy, metal, and grain commodities show high jump correlations [6]. The global spread of the COVID-19 epidemic caused upheaval in the world financial system, prompting an urgent need to reassess gold as a secure haven for finances [7].

The objective of the paper is to map the development of selected metal commodity prices, specifically, gold and silver, in the period 1 January 2015 – 1 January 2023, to determine possible impact of the COVID-19 pandemic on the development of their prices, and to find out whether there is a linear relationship between the commodity prices. To achieve the objective set, the following research questions are formulated:

By answering this research question, it is possible to determine the development of gold and silver prices over the last eight years. The data are then used to answer RQ3.

RQ1: How did the gold and silver prices evolve in the years 2015-2023?

The question will be answered using the comparison of gold and silver prices in the period 1 January 2019 – 1 January 2023. The COVID-19 epidemic was declared pandemic by the WHO on 30 January 2020. By comparing the development of prices in this period, it is possible to determine the impact of the pandemic on the development of individual commodities.

RQ2: What was the impact of the COVID-19 pandemic on the development of the gold and silver prices?

By answering this research question, it will be possible to determine whether there is a relationship between the price of gold and silver, i.e., how the price of one commodity influences the price of the second one.

RQ3: Is there a linear relationship between the prices of gold and silver?

2 Literary research

Resistance to corrosion, rarity, and value represent basic properties that make gold a suitable medium of exchange in the financial and business sphere. Gold is a safe way to store funds in the case of a financial crisis or instability and volatility in world markets. What is even more important is the fact that it is used as an economic benchmark for the global economy and will continue to play an important role in the global economy [8]. Besides buying and selling gold physically, some markets also enable electronic gold trading [9]. The movement of prices of gold as the preferred investment tool is gaining attracting an increased attention. Compared to macroeconomic factors, financial speculation shows stronger explanatory power on changes in gold returns, because international speculative forces are becoming increasingly more active. [10].

The unique properties of silver, enable using it for many applications. [11]. As with most commodities, silver price is determined by speculations on the side of supply and demand, which makes the price of silver volatile due to a smaller market, lower market liquidity, and demand fluctuations between industrial and storage uses [12].

The impact of the COVID-19 pandemic on the price volatility is different in the case of financial assets and precious metals assets. While the infection speed, i.e., the number of people infected with COVID-19, amplify the effect on the tendency towards a high price volatility regime for S&P 500 and FTSE 100 indices, in the case of futures, the effect of the infection speed as well as the number of deaths on gold and silver is moderated, which implies that the gold and silver markets act as risk-hedging safety assets alternative to financial assets during the COVID-19 turmoil [13].

[14] used a quantile cointegration model to demonstrate the relationship between the prices of gold and silver. While cointegration models, which assume constant cointegration vector, are not able to identify cointegration relationship between the prices of gold and silver, the author proved the existence of a non-linear long-run relationship. The cointegration vector was modelled as dependent on state and varied over time. The results indicate that the significant role of precious metals as investment opportunities, especially in period of economic upheavals, leads to the interdependence of gold and silver in these periods.

[15] examined whether the role of gold changes as a result of the introduction of gold exchange-traded funds (ETF) on the basis of sample data from seven countries where physically-backed gold ETFs have been issued. The results show that the traditional role of gold really changes after the introduction of gold ETFs, especially in the corresponding stock markets. [16] delves into the volatility of silver prices post the financial crisis of 2007-2009. Using a structural vector autoregression (VAR), it aimed to examine how sensitive silver prices are to fluctuations in

macroeconomic factors and to assess the reciprocal impact between changes in these variables and silver prices. The key findings revealed that silver prices demonstrate a notable responsiveness to shifts in the gold price, trending relatively sideways. [17] uses several machine learning tree-based classifiers (bagging, stochastic gradient boosting, random forests) to predict the price direction of gold and silver exchange traded funds. [18] conducted an analysis that used quantile regression to assess safety in the context of market volatilities in equities, gold, gold mining and silver. Their findings suggested that gold mining stocks may be an effective alternative to gold itself, as there is a negative correlation of returns between these assets. [19] indicate that people involved in financial markets should carefully consider how much of their portfolio is invested in precious metals markets, especially in the context of the bubble correlation between gold and silver, and especially in times of crisis. Correlation analysis is one of the fundamental mathematical tools to identify the dependence between classes [20]. This type of analysis was used by [21] to identify processes and analyse.

Using the Granger causality test in different parts of the value distribution, [22] confirmed the protective role of precious metals (such as gold, platinum and silver) against risks associated with political relations between China and the United States. The results of the Granger test suggest a mutual causality between current and future returns on gold, silver and their futures [23]. [24] presents empirical evidence regarding the relationship between the gold price and stock market price indices over the period from January 2010 to December 2016. This evidence was obtained using Johansen's cointegration test and Granger causality test.

Secondary data analysis can be a benefit for advanced academic researchers, as it provides large data samples and various data on multiple topics [25]. Qualitative content analysis is a research method conducted either inductively or deductively [24] Quantitative information represent “hard” data, which are considered more persuasive than qualitative data [26]. The purpose of the content analysis/Purpose content analysis is a methodology used in many academic disciplines as a tool to obtain quantitative measures from textual information. Content analysis can be used for data mining and is useful in examining a wide variety of data, including textual, image, and audio datasets [27].

Data collection in the research will involve content analysis, and relationship will be examined using a non-parametric correlation coefficient. Subsequently, cointegration analysis will be conducted using Johansen's cointegration test and Granger causality test.

3 Methods and Data

For the purposes of this paper, content analysis is primarily used for secondary data collection. The findings are analysed using correlation analysis, graphical analysis, and comparative analysis, which will enable answering all the research questions formulated.
The first research question will be answered using the content analysis, which will analyse data obtained from the Kurzy.cz [28] website and the Czech Statistical Office (ČSÚ, 2023). The period under study is 1 January 2015 – 1 January 2023. Data will be monitored at the beginning of each month and recorded in an MS Excel spreadsheet. The subject of each observation is the gold price in individual years in CZK/g. The obtained data are then graphically processed and used for answering the third research question.

Data necessary for answering the second research question are analysed using quantitative content analysis based on the data obtained from the Czech Statistical Office (ČSÚ, 2023) and Kurzy.cz (Kurzy.cz, 2023). There will be monitored the development of the prices of gold and silver in the period 1 January 2019 – 1 January 2023 and subsequently, both trends will be compared. Data will be monitored at the end of each month and recorded in an MS Excel spreadsheet. The monitored period is selected so that it covered the year before the outbreak of the COVID-19, the year in which the pandemic started, and the period after the massive spread of the virus stopped. These results enable understanding the impact of the COVID-19 pandemic on the development of both metal commodities´ prices.

To be able to answer the third research question, data obtained to answer the first research question. Correlation analysis with the help of Kendall’s Tau B and Sperman correlation coefficient will be used to confirm possible existence of the linear relationship between the prices of gold and silver. This is a sample correlation coefficient, which can be calculated as follows:

Kendall’s Tau is calculated using the formula below [29]:

$$Kendall's\ Tau\ B = \frac{n_c - n_d}{n\,(n-1)/2} \quad (1)$$

Where:
nc number of concordant pairs
nd number of discordant pairs
n number of samples

Spearman correlation coefficient is calculated using the formula below [29]:

$$r_s = 1 - \frac{6\sum_{i=1}^{n}(r_x - rY_i)^2}{n(n^1-1)} \quad (2)$$

Where:
n is the number of values in samples *X* and *Y*
rXi order of i-th value in sample *X*
rYi order of i-th value in sample *Y*

If the correlation coefficient equals zero, there is no linear dependence between the variables. Positive values indicate a directly proportional relationship, i.e., the price of one commodity grows with the rising price of the second commodity. Negative values suggest an indirectly proportional relationship, i.e., the price of one commodity decreases with a rising price of the second commodity. The closer the value of the correlation coefficient is to one or minus one, the stronger the linear relationship is. The chosen significance level α is 5 %.

Granger causality will be applied to identify and analyse the relationship between the evolution of silver and gold in a time sequence of data. This test will allow to assess whether the past values of one metal can predict the current or future values of the other metal.

To determine Granger causality between two variables *X* and *Y*, regression models are used:

$$Y_t = a + \sum_{i=1}^{p}\beta_i Y_{t-i} + \sum_{j=1}^{q}\gamma_j X_{t-j} + \varepsilon_t \quad (3)$$

$$Y_t = a' + \sum_{i=1}^{p}\beta_i' Y_{t-i} + \sum_{j=1}^{q}\gamma_j' X_{t-j} + \sum_{k=1}^{r}\delta_k' Y_{t-k} + \sum_{l=1}^{s}\eta_l X_{t-1} + \varepsilon'_t \quad (4)$$

Where:
yt is the value of variable *Y* at time *t*
Δyt is the change in the value of variable *Y* at time t
xt-i is the value of variable X at time t-i
α are intercepts (initial values) in regression models.
βi are coefficients for past values *Y* in the first and second regression models
γ_j are coefficients for past values *X* in both models.
p, q, r, s are the delays (time intervals) used for past *X* and *Y* values in the models
$\mathcal{E}_t$ random errors are unexplained patterns

The Johansen cointegration test will be used to analyse the long-run relationships between time series (gold and silver). This test will be used to determine the number of cointegration

relationships between multiple variables. Cointegration is a concept that describes that although individual variables may move independently in the long run, there is a long-run equilibrium relationship between them.

It can be expressed as a *p-th* order VAR (Vector Autoregression) model for *k* time series Y_t, as:

$$Y_t = IIY_{t-1} + \varepsilon_t \quad (5)$$

Where:
Y_t is vector of time series
II is a coefficient matrix
ε_t is an error vector

The Johansen test is then carried out using eigenvalue analysis of the matrix *II*. The testing consists of estimating the eigenvalues of matrix *II* and determining how many of them are statistically significant. If there are *r* eigenvalues that are statistically significant, then there are said to be *r* cointegrating vectors. To verify the normality of the data, it is necessary to refute or confirm the formulated null hypothesis, for which an alternative hypothesis is formulated as follows.

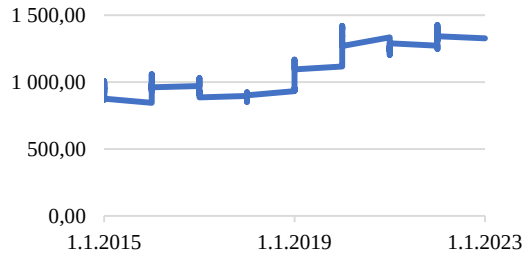
H0: There is a linear relationship between the prices of gold and silver.

H1: There is no linear relationship between the prices of gold and silver.

4 Results

Data on the prices of both commodities were monitored always on the first day of each month. A table showing the prices of gold and silver in the monitored period is presented in the appendix.

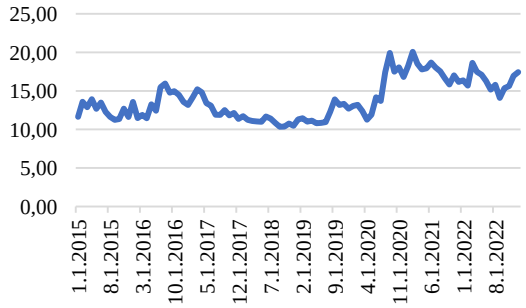
Graph 1. Trend of gold prices in [CZK/g]



(Source: Authors according to Kurzy.cz, 2023)

Graph 1 shows the trend of the gold price in the period 1 January 2015 – 1 January 2023. The data about the prices of this commodity were obtained from the Kurzy.cz website and are given in CZK/gram. The maximum gold price was recorded in March 2022. From 2015, the price of gold grew by approx. 51 %. In the period 1 January 2015 – 1 February 2015, one of the biggest price jumps in the gold price was recorded, specifically, an increase of approximately 15 % compared to the preceding month; between 1 February 2022 – 1 March 2022, the increase was about 14.5 %.

Graph 2. Trend of silver prices in [CZK/g]

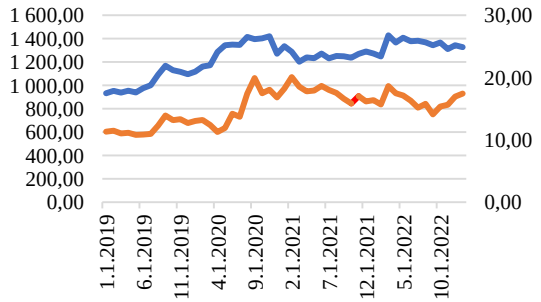


(Source: Authors according to Kurzy.cz, 2023)

Graph 2 shows the development of the silver prices between 1 January 2015 and 1 January 2023. The data about the prices of this commodity were obtained from the Kurzy.cz website and are given CZK/gram. As seen in the graph, the maximum price was recorded in February 2021. From the year 2015, the price of silver grew by about 50 %.

Graph 3. The impact of COVID-19 pandemic on commodity prices [CZK/g]

(Source: Authors according to Kurzy.cz, 2023)



Legend: Blue – price of gold (CZK/g); Orange – price of silver CZK/g)

Graph 3 shows the impact of the COVID-19 pandemic on the prices of gold and silver. The monitored period covers the year before the pandemic, during the peak of the pandemic (declared by the WHO on 30 January 2020), and the period until the beginning of 2023, when the COVID-19 virus and its mutation were still active, but the number of infected people fell sharply, and the pandemic crisis was on the wane. As seen in the graph, the situation had an impact on the prices of both commodities. The development of gold prices showed a gradual growth without any significant price jumps; however, considerable fluctuations could be observed. Within the monitored period, the price of gold rose from the initial 877,19 CZK/g to 1,327 CZK/g on 1 January 2023, while the price of silver rose from 11,31 CZK/g to 17,43 CZK/g. The results thus confirm that the COVID-19 pandemic had an impact on the development on the gold and silver prices. In times of crisis, gold serves as a hedging investment metal, as its value increases during global crises.

Table 1. The results of the correlation according to Kendall's Tau - B

	gold	silver
Gold	1	
silver	0.61	1

(Source: Authors according to Kurzy.cz, 2023)

According to Table 1, the calculation of the dependency using Kendall's Tau - B correlation coefficient resulted in 0.61, which falls within the boundary between moderate and strong linear dependence.

Table 2. The results of the correlation according to Spearman correlation coefficient:

	gold	silver
Gold	1	
silver	0.8	1

(Source: Authors according to Kurzy.cz, 2023)

Using Spearman's correlation coefficient yielded a value of 0.8, indicating a strong linear dependence, as presented in Table 2. The calculations were conducted at a significance level of 5 % and are statistically significant.

Figure 1 Granger causality test for silver

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Model 1: vilda_test$gold ~ Lags(vilda_test$gold, 1:3) + Lags(vilda_test$silver, 1:3
Model 2: vilda_test$gold ~ Lags(vilda_test$gold, 1:3)
  Res.Df Df      F    Pr(>F)
1     87
2     90 -3 5.68042 0.0013375 **
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(Source: Authors according to Kurzy.cz, 2023)

The result of the Granger causality for silver is 0.013375, computation was performed using Lags = 3, as shown in Figure 1. The results reach values below 0.05, which represents the set significance level for statistical analysis.

Figure 2 Granger causality test for gold

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Model 1: vilda_test$silver ~ Lags(vilda_test$silver, 1:3) + Lags(vilda_test$gold, 1:3)
Model 2: vilda_test$silver ~ Lags(vilda_test$silver, 1:3)
  Res.Df Df      F    Pr(>F)
1     87
2     90 -3 4.48313 0.0056478 **
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(Source: Authors according to Kurzy.cz, 2023)

The Granger causality result for gold is 0.0056478. This value indicates a statistically significant relationship between past values of another variable and the price of gold. In the context of Granger causality, this result indicates the existence of a statistically significant causal relationship. The results confirm the null hypothesis and do not support the acceptance of the alternative hypothesis.

H0: There is a linear relationship between the prices of gold and silver.

Figure 3 Johansen's cointegration test

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######################
# Johansen-Procedure #
######################

Test type: trace statistic , with linear trend

Eigenvalues (lambda):
[1] 0.1643804997792476 0.0172509125744634

Values of teststatistic and critical values of test:

          test 10pct  5pct  1pct
r <= 1 |  1.64  6.50  8.18 11.65
r = 0  | 18.52 15.66 17.95 23.52
```

(Source: Authors according to Kurzy.cz, 2023)

The result of the Johansen cointegration test showed that the cointegration vector (r) that was plotted exceeded the specified significance level. This result indicates the existence of one cointegration vector among the variables under study. This can certainly be seen in the calculation shown in Figure 3.

5 Discussion

Based on the results obtained, it is possible to answer the research questions:

RQ1: How did the price of gold and silver evolve in the last eight years?

The data needed to answer this research question were obtained using a content analysis and processed and evaluated using a graphical analysis. At the beginning of the monitored period, the price of gold was 877, 19 CZK/g. From the year 2015, the price of gold rose by approx. 51 %. The maximum price (1,428,29 CZK/g) was recorded in March 2022. In the period 1 January 2015 – 1 February 2015, one of the biggest price jumps was recorded of approx. 15 %. Another large fluctuation was recorded between 1 February 2022 and 1 March 2022 (a rise by about 14.5 %). The price of silver was 11,64 CZK/g at the beginning of the monitored period. From the year 2015, the price of silver rose by approximately 50 %, with the maximum price being recorded in 2021, reaching the value of 20,8 CZK/g. The results thus indicate a similar price development of both commodities.

The price of gold can be affected by inflation because gold is often seen as a safe investment and storage value in times of economic uncertainty or in periods when inflation is rising. When inflation rises, the value of money falls, which may encourage investors to seek assets that hold their value better than traditional currencies this is also confirmed [30] in their work. Gold is considered an "inflation hedging" instrument because its value historically increases during periods of high inflation, offering protection against a decline in the purchasing power of the currency.

RQ2: What was the impact of the COVID-19 pandemic on the development of the gold and silver prices?

The results show that this situation affected the price development of both commodities. The COVID-19 pandemic had a significant impact on the gold price. During the period of uncertainty and economic turmoil caused by the pandemic, investors looked for safe assets and resorted to traditional havens such as gold. During the pandemic, investors favoured assets with less risk, which led to a growing demand for gold and a subsequent increase in its price. This phenomenon is a typical example of how instability in the global economic environment can affect investor behaviour and cause a shift in the price of commodities such as gold.

[13] examined the impact of the COVID-19 pandemic on the volatility of financial assets and metal prices. The findings of the author are thus in line with the findings resulting from the presented research, stating that from the perspective of investment, the COVID-19 pandemic had a positive impact on the price development of these commodities, which can thus be considered hedging assets and alternatives to financial assets in times of economic crises.

RQ3: Is there a linear relationship between the prices of gold and silver?

The value of the correlation coefficient obtained through a correlation analysis were 0,61 (Kendall) and 0.80 (Spearman) after rounding. It can thus be concluded that there is a very strong linear dependence between the prices of gold and silver. If the value of one variable increases, the value of the other variable rises as well. The significance level, which was set at 5 %, is lower than the value of the correlation coefficient; therefore, the alternative hypothesis H1 is rejected and the null hypothesis H0, stating that there is a linear relationship between the prices of gold and silver, is accepted.

In his study, [14] used a quantile cointegration model to prove the relationship between the prices of gold and silver. The authors agree with the finding that there is a relationship between these two commodities, especially in the periods of economic turmoil.

Based on the proven Granger causality, it can be assumed that information about the price of gold can be derived from silver values and vice versa. This statistical test shows the possible predictive power of past silver values in predicting future gold prices and vice versa. Such correlations between gold and silver prices may be due to several factors. These include the more common use of both metals as investment tools in the search for safe assets in times of economic uncertainty.

6 Conclusion

The objective of the paper was to map the development of the selected metal commodities – gold and silver between 1 January 2015 and 1 January 2023, to determine whether the COVID-19 pandemic had any impact on the development of their prices, and whether there is a linear relationship between the prices of these two commodities. The objective of the paper was achieved.

The price of both metal commodities rose in the monitored period. At its beginning, the price of gold was 877,19 CZK/g, while the final price was 1,327 CZK/g. Similarly, the price of silver grew as well in the monitored period, rising from the initial value of 11,64 CZK/g to 17.43 CZK/g. The curves of both commodities showed a similar trend.

Furthermore, it was found that the COVID-19 pandemic affected the price development of both commodities. Its influence was positive from the perspective of investment, as the prices of both commodities grew significantly. Before the pandemic, the price of gold ranged between 932,79 – 1 095,15 CZK/g, while the price of silver was between 11,31 and 12,69 CZK/g. After the end of the peak of the COVID-19, the price of gold was about 1,327 CZK/g and the price of silver about 17,43 CZK/g. This implies that mainly gold can serve as an investment metal in times of economic crises.

The results of the correlation analysis confirmed the existence of a linear relationship between the prices of gold and silver. The value of the correlation coefficient equals 0,61 (Kendall) and 0.80 (Spearman) after rounding, which indicates a very strong linear dependence. In practice, a positive correlation coefficient means that if the price of one commodity increases, the price of the other commodity will grow as well and vice versa.

The biggest limitation of this research was the COVID-19 pandemic and the war in Ukraine. These two events influenced the development of both commodities´ prices and were thus reflected in the research results. The correlation between the prices of gold and silver may be the result of various factors, including their role as investment instruments in periods of economic instability, when investors seek safe haven in one of the metals depending on the market situation. This highlights the complexity of the interactions between these commodities and demonstrates their importance as indicators of market sentiment during periods of economic volatility.

A recommendation for further research is to collect the data again after the effects of the global crisis have subsided and to make new calculations and compare whether the results will match. Furthermore, it is recommended to increase the frequency of data collecting, i.e., collect data not only at the beginning of each month. With a higher frequency, more accurate results could be obtained.

The findings could be used also for predicting the future development of the gold and silver prices.

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Primary Paper Section: A

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