Cointegration Analysis of US M2 and Gold Price Over the Last Half Century

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Abstract:

In this article I have analysed the long-term relationship between US M2 money supply and the price of gold per troy ounce using Engle-Granger cointegration. The analysis shows the existence of long-term price dependency of gold in relation to US M2 money supply. M2 was used in two variants, seasonally adjusted and not seasonally adjusted. No relevant difference was observed between them. A period spanning 53 years, from 1970 to 2023, was analysed. An EC model using monthly observations indicates very weak correlation between the change of M2 and the subsequent change of the gold price, so semiannual observations were used instead which proved fully conclusive. This, together with results from the long-term model, confirms long price cycles and fluctuation around its equilibrium price lasting for years, which allows the use of gold as a hedge against increasing M2. This article may prove beneficial in filling the gap as it confirms gold price to be dependent on US M2 on longer time span analysed than previous studies and is fully able to explain gold price analysing dependency of two variables only.

Keywords: Cointegration Analysis; Gold; M2; Money Supply.

JEL classification: C58; E31; E44; E51; G12.

1 Introduction

Gold is a popular investment tool that allows investors to hedge to a certain extent against the negative effects of high inflation, political or economic instability. Gold is also included in the portfolio for the purpose of achieving return and diversifying risk. On the other hand, physical gold is a non-productive asset that does not provide any income during its holding period. The gain from a holding period linked to this asset is derived from the difference between the sale and purchase price. At the same time, the actual amount of real gain is affected by inflation. When assessing the success of an investment, other investment alternatives must also be taken into account to assess the opportunity cost. Investing in gold, which is associated with risk, should yield a higher return than government bonds, which are considered risk-free.

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M2 money supply is an important macroeconomic aggregate monitored by central banks and analysts. US M2 is a measure of US money stock that includes M1 (currency and coins held by the non-bank public, checkable deposits, and travellers' checks) plus savings deposits (including money market deposit accounts), small time deposits under USD 100,000, and shares in retail money market mutual funds (Neely, 2023).

Macroeconomic aggregates such as M2, GDP, etc. are often analysed by portfolio managers or fundamental analysts who assume links between the development of the aggregates and the prices of the investment instruments in the portfolio.

The objective of this article is to examine the possible relationship between the price of gold and the US monetary aggregate M2 over the longest possible time period allowed by available data. The results of this study, (*i.e.*, new, up-to-date information on the relation of the price of gold to M2), can be used by institutional and retail investors in the asset allocation process with the aim of increasing their performance, reducing risk or both. Detailed knowledge of the relationship between the price of gold and M2 can fundamentally affect the success of the investments made by the aforementioned investors.

The contribution of this study is an analysis of the relationship between the gold price and the important macroeconomic aggregate M2 over a long period of more than five decades. Focusing on only two variables allows for a more detailed analysis based on actual data over a longer period of time than has been done in some earlier studies and finally confirms relationship of gold price on just one significant factor.

The long-term relationship between M2 and inflation has been described, for example, in a study by De Grauwe and Polan (2005) which focused on 160 countries over a period of 30 years and is also confirmed by another study of Hallman *et al.* (1991) which focused on the relationship between the money supply and the price level in the United States in a period spanning from the Korean War to year 1991. Any confirmed relationship between M2 and the price of gold in this article can be beneficial for investors when using the findings from these aforementioned studies when a hedging against inflation is needed.

The remainder of this article is structured as follows. In Section 2, a literature review summarises previous research and debates on this topic. Section 3 explains the econometric models and data sources used, including the Engle-Granger cointegration test. Section 4 highlights the findings of the analysis, emphasising the long-term relationship between M2 and gold prices while addressing short-term dynamics. Finally, Section 5 summarises key insights, practical implications, and limitations of the study, providing guidance for future research.

2 Literature Review

The connection between money supply and gold price has been discussed since as early as the 19th century when it was claimed that the growing quantity of pound sterling in circulation in England was responsible for the increasing price of gold (Ricardo, 1810).

It was found that by increasing the money supply, the price of gold price rose as well but lagged by about six months. Gold price is influenced by many factors world-wide and as such, change of money supply in India, Europe, and Turkey also influence its performance. In particular, a 1% change in money supply in the US, the European Union, United Kingdom, India, and Turkey tends to correlate to an increment in the price of gold by 0.9%, 0.5%, 0.7%, and 0.05%, respectively. Moreover, it was found that changes in the US money supply do not solely explain changes in the price of gold. Gold also reacts on future velocity of money, particularly in the US (Artigas, 2010).

Analysing money supply measured by M2 in a period from 1980 to 2020 using quarterly data brought surprising results in that rise in the quantity of money in a two time period anticipates a fall in future gold prices (Gonçalves and Alves, 2022).

In addition, many metrics associated with central bank monetary policies - not only money supply, but also interest rate - have been proved to influence gold prices. However, fiscal policies can also impact gold price as periods of increasing fiscal deficits across the globe have a tendency to trigger gold prices appreciation (Bapna *et al.*, 2012).

Using VAR analysis proved that changes in real GDP, short-term interest rates and money supply measured by M2 are not correlated with the real rate of return on gold (Lawrence, 2003).

On the other hand, some studies do not mention any connection between gold price and money supply and highlight other factors responsible for gold price determination.

One such study found that from 1971 to 2001 gold price was primarily determined by the level of central bank sales of gold reserves and stock market activities as well as the value of the US dollar and gold production-fabrication forces (Elfakhani *et al.*, 2009).

In another study it was found that the price of gold positively responded to the announced changes in deficit projections by US Federal (Kitchen, 1996).

This is also confirmed by intraday data over a period of four years (1992–1995) which indicated, that the price of gold responded to the release of federal deficit, the unemployment, rate capacity utilization, consumer price index, gross domestic product and producer price index (Christie–David *et al.*, 2000).

Generally, studies on inter-dependency of gold price and money supply provide mixed results, usually confirming the influence of money supply on gold price with some exceptions (Gonçalves and Alves, 2022), but further or alternative explanatory variables such as inflation, GDP, fiscal policy, etc. are needed in order to confirm this relationship.

Many studies have been carried out on the relationship between gold price and inflation and, assuming a possible relationship between the growth of money supply and inflation, such studies are also relevant.

It was analysed hypothesis if gold can act as a safe haven asset in developed markets during periods of market shocks. The results showed when extreme negative and short-term shocks occur investors react by buying gold. On the other hand, gold does not act as a safe haven during long-term extreme levels of global uncertainty when the price of gold moves together with price of equities. This research however, found that gold has the potential to act as a stabilising force for the global financial system by reducing losses when it is needed most (Baur and McDermott, 2010).

A study on the hedging ability of gold and the long-term relationship between its price and inflation has examined a period spanning January 1971 to January 2010 with data available for Japan and USA along with inflation data CPI provided by the IMF and International Financial Statistics. In the long run, gold price rigidity negatively affects gold hedging ability while, in the short run, this study examines low and high momentum regimes. With low momentum regimes price of gold is unable to hedge against inflation in both the US and Japan, as well. On the other hand, during high inflation regimes it is only in the US that gold return is able to hedge against inflation (Wang *et al.*, 2011).

A further study on the relationship between inflation and the price of gold offers proof that gold is partially able to hedge against the CPI and the PPI in the US and UK, the Euro Area and Japan (Beckmann and Czudaj, 2013).

Another author argues that although gold investments do not provide a perfect hedge against inflation, investors are advised to use gold both to diversify their investment portfolio and to protect against rising general price levels. The main reason is that a rise in inflation reduces the real value of money and people seek to invest in alternative investment options such as gold to preserve the value of their assets and to gain additional returns (Naser, 2017).

In a study looking at over two hundred years of data it has been found that gold is an inflation hedge in the long run for both the USA and the UK (Bampinas and Panagiotidis, 2015).

When it comes to understanding the ability of CPI indices in different countries to predict the US dollar price of gold, results from study covering 54 different countries show that UK and US CPI rates have, among others, predictive powers in relation to the London gold price while this evidence is found to be stronger for out-of-sample tests than for in-sample tests (Sharma, 2016).

On the other, hand in a paper examining the relationship between gold and inflation in China, India, Japan, France, the United Kingdom and United States (between years 1978–2015), works with a nonlinear autoregressive distributed lags (NARDL) model and has proved that gold was not a hedge in the long-run for all the observed countries (Hoang *et al.*, 2016).

An analysis of the stock market, CPI and gold price in the United States for a 25-year period (1996–2020) uses monthly averages of observed values. Time series cointegration analysis was used to analyse the relationships and summarising the results obtained, shows a strong impact of inflation on both the stock index and gold price. The market price of gold was also partly influenced by the development of market stock prices (Revenda and Arltová, 2022).

A summary of results of studies on relationship between gold price and inflation provide inconsistent results. While some of them confirm this link (Bampinas and Panagiotidis, 2015), others do so only under some conditions (Wang *et al.*, 2011), while further studies reject this thesis altogether (Hoang *et al.*, 2016).

3 Data and Methodology

A theoretical solution of the problem is provided by the neutrality of money in the long run explained by the equation of exchange (Fisher, 1911):

$$M \times V = P \times Q, \tag{1}$$

where M is the total amount of money in circulation, V means velocity of money in circulation, P represents price level, and Q is quantity of output exchanged. When M is increasing proportionally more than Q (while not being offset by a decrease in V) price level P is increasing, as well.

In other words, long-term money neutrality supposes in the long-term that a change in the level of money supply affects only nominal variables in the economy with no effect on real variables. A stronger feature than money neutrality is money superneutrality. It holds that level of the money supply not only does not affect the real economy, but also that the growth rate of money supply has no effect on real variables. It should be said that the neutrality of money works under the assumption of rational expectations. If there is an unexpected change in the money supply (or a change in the growth of the money supply), it may not hold (Lucas, 1972).

As a practical method two-step Engle-Granger cointegration test was used, consisting of estimating OLS model and then ECM (error correction model).

3.1 Exogenous variable

As an exogenous variable, I chose the US M2 monetary aggregate in two variants. The first seasonally adjusted ($M2SL$) and the second not seasonally adjusted ($M2NS$). Data published once a month were available and, in total, there are 637 observations from February 1970 to December 2022 from the FRED database (Federal Reserve Bank of St. Louis, 2023a; 2023b).

M2 not seasonally adjusted saw a growth from USD 583.40 bil. in February 1970 to USD 21,366.60 bil. in December 2022, an increase of 36.62 times its original value and representing 7.03% growth per year.

M2 seasonally adjusted, meanwhile, rose from USD 586.30 bil. in February 1970 to USD 21,207.40 bil. in December 2022, which is an increase of 36.17 times its original value representing 7.00% growth per year.

In Tab. 1 is given summary statistics of time series of M2 using the observations in period from February 1970 to February 2023.

Tab. 1 M2 statistics (1970/2–2023/2, in USD bil.)

Variable	Mean	Median	Min	Max	*SD*	CV	Skewness	Ex. kurtosis
$M2NS$	5888.8	3734.1	583.40	21856.	5183.2	0.88019	1.3115	1.0855
$M2SL$	5888.8	3737.1	586.30	21740.	5183.2	0.88019	1.3115	1.0855

Source: Federal Reserve Bank of St. Louis (2023a; 2023b) + authorial computation.

3.2 Endogenous Variable

As an endogenous variable gold price time series data from February 1970 was chosen as previously the dollar was pegged to gold and the price fluctuated within a narrow range. In the period of January 1934 to November 1967 in particular, the price moved between USD 31.88–35.31 per troy ounce (Macrotrends, 2023). After fall of Bretton Woods System in 1971, the stable price of gold was destabilised (Office of the Historian, n.d.).

Gold price during the observed period grew from USD 35.20 in February 1970 to USD 1,865.13 in February 2023, which is an increase of 52.99 times its original value during 53 years and represents 7.78% growth per year.

In Tab. 2 is given summary statistics of time series of price of gold (in USD) per troy ounce using the observations in period from February 1970 to February 2023.

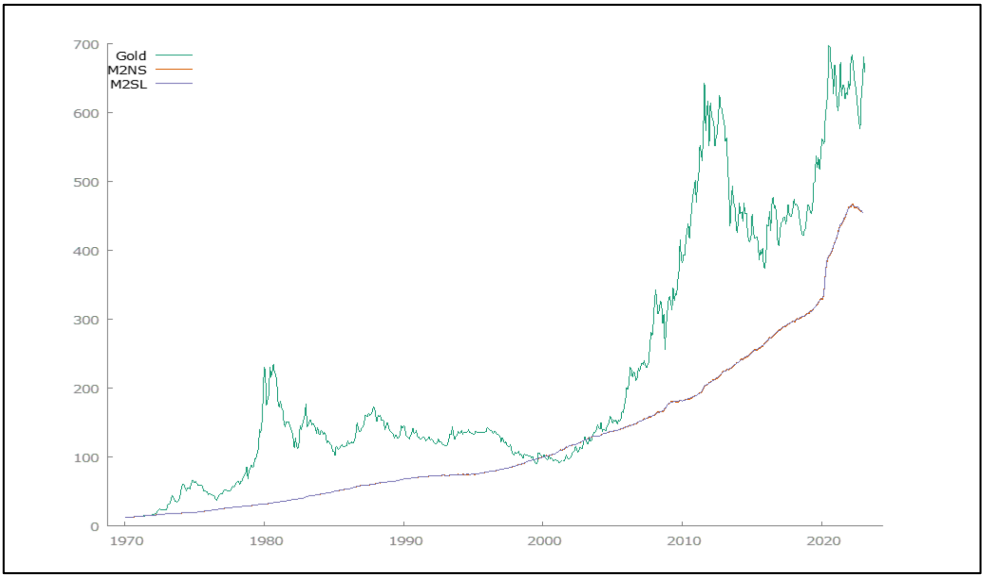
Tab. 2 Statistics of time series of price of gold (1970/2–2023/2, in USD)

Variable	Mean	Median	Min	Max	*SD*	CV	Skewness	Ex. kurtosis
gold	630.03	388.96	35.200	1975.9	519.84	0.82511	1.0487	−0.21474

Source: Macrotrends (2023) + authorial computation.

In Fig. 1 is comparison of time series, concretely M2 seasonally adjusted and not adjusted against M2.

Fig. 1 Selected variables against M2 index 2000=100



Source: Federal Reserve Bank of St. Louis (2023a; 2023b), Macrotrends (2023) + authorial computation.

3.3 Econometric model

Firstly, I estimated the model using the ordinary least square method in the following form:

$$gold_t = \alpha + \beta_1 M2_t + u_t, \quad (2)$$

Where $gold$ is price of gold per troy ounce, α is the intercept, β_1 represents parameter of variable, $M2$ is money supply M2 in US and u_t is an error term.

To remove skewness described in Tab. 1 and Tab. 2 and reduce potential heteroskedasticity I logarithmised each time series. I denote the new variables by l to make it clear that they are logarithmic variables.

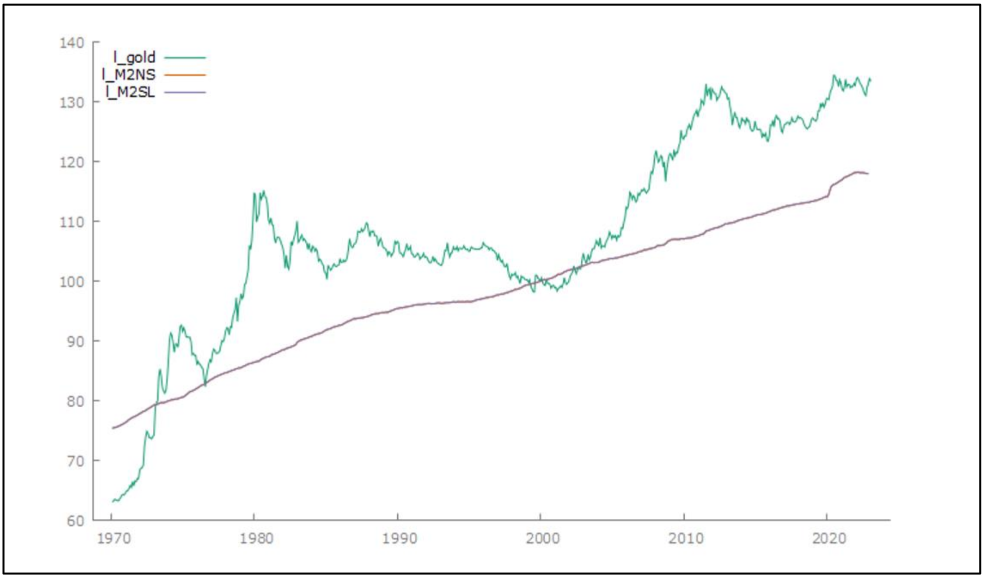
Statistics of newly created variables are given in Tab. 3 and their graphical comparison in the form of time series in Fig. 2.

Tab. 3 Descriptive statistics of logarithmic variables

Variable	Mean	Median	Min	Max	*SD*	CV	Skewness	Ex. kurtosis
l_gold	6.0789	5.9635	3.5610	7.5888	0.92360	0.15194	−0.49539	0.25055
l_M2NS	7.8861	8.0978	5.6619	9.9922	1.2174	0.15437	−0.20923	−1.0588
l_M2SL	7.8861	8.0955	5.6581	9.9869	1.2174	0.15437	−0.20919	−1.0589

Source: Federal Reserve Bank of St. Louis (2023a; 2023b), Macrotrends (2023) + authorial computation.

Fig. 2 Selected log variables against M2 index 2000=100



Source: Federal Reserve Bank of St. Louis (2023a; 2023b), Macrotrends (2023) + authorial computation.

If the time series of the variables are not stationary, classical regression according to Equation (2) cannot be used, except cases where cointegration is present (Enders, 2014).

The next step, therefore, is to check the stationarity of the variables. A stationary time series is one in which the mean, variance and covariance of the residuals do not change with time (Verbeek, 2008).

3.4 Time series Cointegration

Stationarity

Stationarity testing will be verified by an ADF unit root test (Dickey and Fuller, 1979), being the most appropriate test, even in the case of large length (in our case $T = 637$) time series (Arltová and Fedorová, 2016).

Engle-Granger Test

For the Engel-Granger cointegration test, I chose logarithmised gold price as the dependent variable, while the independent variable was l_M2NS or l_M2SL. I chose the lag order as maximum according to the result of the Akaike information criterion.

EC model

In cases where I found cointegration, *i.e.*, a long run relationship between M2 and the gold price, I further tested the ECM (error correction model) to express the short-run relationship between the variables. That is, when gold price deviates from equilibrium, and for how long, and whether it tends to return to equilibrium. Moreover, this is another confirmation of cointegration since if the short-run relationship is missing and the endogenous variable deviates far from the equilibrium position, it brings it back to equilibrium. Then, the long-run relationship – cointegration is not possible (Engle and Granger, 1987). The EC model was built according to Equation (3) while the error correction term was constructed from residuals from Equation (2) delayed by one period.

$$\Delta y_t = \beta_1 \Delta x_t + \rho_1 \hat{u}_{t-1} + \varepsilon_t, \quad (3)$$

where Δy represents the first difference of endogenous variable, β_1 is the parameter of variable, Δx is the first difference of exogenous variable, ρ_1 is the parameter of error correction term, $\hat{u}_{t-1}$ is the error correction term estimated from residuals from Equation (2) lagged by one period and ε_t is an error term.

4 Results and Discussion

The results of regression according to Equation (2) are shown in Tab. 4 and Tab. 5. High R^2, and the significance of all parameters including F-test for the whole model were found for all exogenous variables examined.

This is a common symptom of time series and so-called spurious regression, so next step was testing for time series stationarity which is prerequisite before cointegration testing is performed (Engle and Granger, 1987).

Tab. 4 Model 1

Variable	**Parameter**	***p*-value**
Const	−1.17636	0.0000
l_M2NS	0.875866	0.0000
Tests		
Breusch-Pagan		*p*-value 0.0000
R^2		0.806916
Durbin-Watson		0.018393
F-test		*p*-value 0.0000

Source: Authorial computation.

Tab. 5 Model 2

Variable	**Parameter**	***p*-value**
Const	–1.17622	0.0000
l_M2SL	0.875849	0.0000
Tests		
Breusch-Pagan		*p*-value 0.0000
R^2		0.806886
Durbin-Watson		0.018216
F-test		*p*-value 0.0000

Source: Authorial computation.

The *t*-ratios from Equation (2) are not interpretable, as it is a long-run equation, and therefore (due to misspecified dynamics) will have serial correlation. As such, the distribution of the *t*-ratio is not known which means the traditionally used diagnostic tests are not relevant in estimating the specification quality of model.

A stationarity test was therefore necessary to examine if the Engle-Granger test of cointegration can be further used.

For all logarithmic variables, the augmented ADF test came out at 5% significance that they are non-stationary even in the no-constant, constant and constant with trend tests.

I stationarised the time series by differencing. Thus, all were already stationary at the 5% significance level when tested with the augmented ADF test.

By first-order differencing, I showed that these are I(1) time series that can be tested for cointegration

Results in Tab. 6 show that at the 5% significance level, all analysed time series are non-stationary, of type I(1).

Tab. 6 Stationarity ADF unit root test

Variable	Type of model	Variables in level		1st differences of variables		Integration
		Test statistic	*p*-value	Test statistic	*p*-value	I(d)
l_gold	Without constant	1.25023	0.9467	−4.45023	0.0000	I(1)
	With constant	−2.3703	0.1503	−5.07343	0.0000	I(1)
	With constant and trend	−3.39407	0.0521	−5.14443	0.0000	I(1)
L_M2NS	Without constant	3.2648	0.9998	−2.28432	0.0216	I(1)
	With constant	−1.15669	0.6952	−4.2839	0.0005	I(1)
	With constant and trend	−2.45044	0.3532	−4.37072	0.0024	I(1)
L_M2SL	Without constant	3.43378	0.9999	−2.45655	0.0136	I(1)
	With constant	−1.53677	0.5151	−4.58618	0.0001	I(1)
	With constant and trend	−2.88716	0.1666	−4.72469	0.0006	I(1)

Source: Authorial computation.

Tab. 7 *p*-values of Engle-Granger cointegration test with l_gold as an endogenous variable

Exogenous variable	Model without constant	Model with constant	Model with constant and trend
L_M2NS	0.0048	0.0391	0.0509
L_M2SL	0.0049	0.0407	0.0647

Source: Authorial computation.

The Engle-Granger test of cointegration and its results shown in Tab. 7 indicated a long-term relationship between gold price and M2. Best results were obtained by the model with constant and then without constant with both being at the 5% significance level. The model with constant and trend was at 10% significance level.

I also tried swapping the variables, *i.e.*, variables of M2 being the dependent variable and the gold price time series the independent variable to be sure of the causality of the relationship and exclude reverse causality. In this case, there was no rejected null hypothesis meaning there was no Engle-Granger cointegration and M2 is not dependent on gold price.

Tab. 8 EC model 1 endogenous variable d_l_gold

Variable	Parameter	*p*-value
d_l_M2NS	0.735685	0.0007
ρ_1	–0.0125443	0.0653
Tests		
Breusch-Pagan		*p*-value 0.0000
R^2		0.021966
Durbin-Watson		1.945151
F-test		*p*-value 0.0000

Source: Authorial computation.

Tab. 9 EC model 2 endogenous variable d_l_gold

Variable	Parameter	*p*-value
d_l_M2SL	1.15047	0.0001
ρ_1	–0.0126176	0.0647
Tests		
Breusch-Pagan		*p*-value 0.0000
R^2		0.032134
Durbin-Watson		1.933815
F-test		*p*-value 0.0000

Source: Authorial computation.

In the EC model according to Equation (3) heteroscedasticity was present, so I used HAC model.

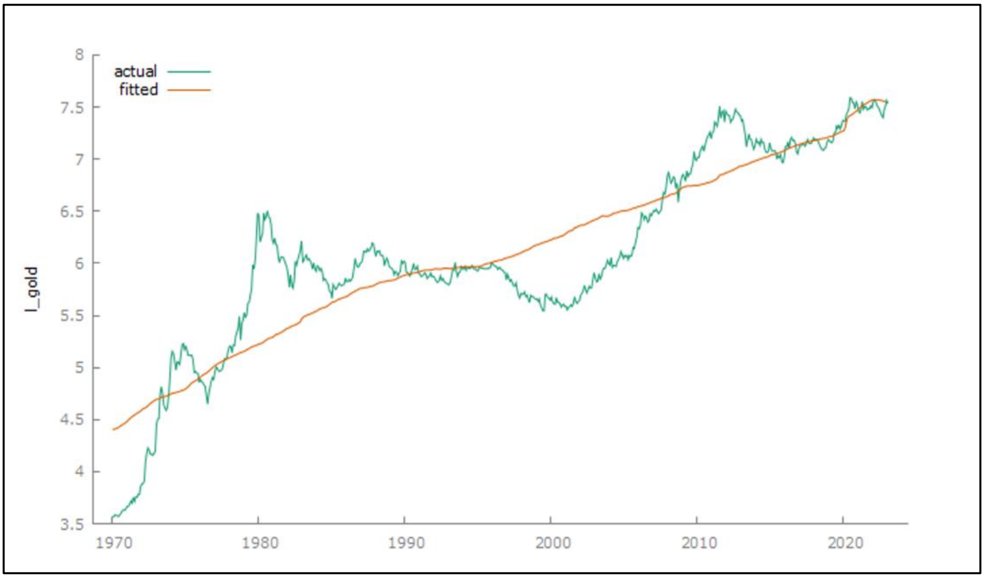
The EC model came out better without the constant. Although the model had a small R^2, variables were statistically significant and the *F*-test of the full model was also conclusive while autocorrelation of residuals was not present. The ECT parameter was negative and while not significant on the 5% significance level, was significant at the 10% level.

The EC model used confirmed the long-term relationship, *i.e.*, cointegration (it is not possible to have cointegration without a functional EC model) by the fact that the ECT parameter has a negative sign and is statistically significant, but at the 10% significance level (6.6% specifically). The ECT had a very small value and this means that once there is a deviation from equilibrium, the return to the equilibrium state takes a very long time, which could in some way indicates that the ECM is not working.

This can be in line with the fact that time series trends in finance often take many years and, in our case, according to the Equations (6) and (7) return to equilibrium takes 1.25% or 1.26% respectively per observation, in this case being monthly.

Specifically, according to Fig. 3, maximum overvaluation during the observed 53 years reached the price of gold in 1980 and again in 2007. In the first case it took ten years to reach equilibrium and in the second case seven years. From undervaluation in 2001 it took six years to reach equilibrium state.

Fig. 3 Actual and fitted price of gold based on model 1



Source: Federal Reserve Bank of St. Louis (2023a; 2023b), Macrotrends (2023) + authorial computation.

The question is whether such an EC model is useful in practice, especially if it has a small R^2 and models are significant not at a 5% level, but at a 6.6% significance level. Here, I think it is important to note that this is probably because the cycles are multi-year and almost no change occurs during our observation period of only one month.

To increase the R^2 and value of ECT of the EC model it might be more appropriate to adjust the data, for example use semi-annual or even annual data, which would mean that change per one period would be significantly higher than in our case and would improve explanatory ability.

To check this thesis semiannual data was chosen to test with the EC model. Results are in Tab. 10 and Tab. 11. Tested data was with the same model according to

Equation (3), again coming out better without constant. Models in comparison with the monthly data model had increased R^2, with variables significant, the F-test of the full model was also conclusive, and autocorrelation of residuals not being present. The ECT parameter was negative, its value was significantly higher, heteroskedasticity was not present and was significant at the 5% significance level.

Results were clearly better than in the case of using monthly data. The ECT parameter indicates return to equilibrium by 8.9% using a period of half a year and in line with multiyear cycles in Fig. 3 and also with an ECT parameter using monthly data in Tab. 8 and Tab. 9 where the ECT parameter was 1.25% and 1.26% respectively.

Tab. 10 EC model 3 endogenous variable d_l_gold

Variable	**Parameter**	***p*-value**
d_l_M2NS	1.03693	0.0043
ρ_1	–0.0893882	0.0127
Tests		
Breusch-Pagan		*p*-value 0.0826
R^2		0.126007
Durbin-Watson		1.648468
F-test		*p*-value 0.0010

Source: Authorial computation.

Tab. 11 EC model 4 endogenous variable d_l_gold

Variable	**Parameter**	***p*-value**
d_l_M2SL	1.02477	0.0049
ρ_1	–0.0894120	0.0127
Tests		
Breusch-Pagan		*p*-value 0.0823
R^2		0.123972
Durbin-Watson		1.652907
F-test		*p*-value 0.0012

Source: Authorial computation.

With these results of the Engle-Granger cointegration and EC model it can be concluded that the two-step Engle-Granger cointegration test confirmed the long-term dependence of gold price on M2, which is in line with Artigas (2010) and his study in which a period from year 1975 to year 2010 was examined.

An interesting is comparison with Gonçalves and Alves (2022) saying that in two periods after increasing M2 a decrease in gold price is anticipated. It is very likely that both claims are correct, since they used ARDL model and examined what happens in a short period of time after an increase of M2. With the EC model I used, when it comes to movement in the quantity of M2, then gold price moves in same direction and in case of disproportionally large/small movements of gold price related to M2 there is a tendency to move back (explained by ECM) to steady state determined by long-term Equations (4) and (5) respectively. This claim is not excluding possibility that after move of M2 can be short period with tendency of countermove of gold price.

Gold price from year 1971 to the end of year 2022 grew 7.78% annually, while M2 grew 7% per year. In this sense, gold can be considered one of the "real" assets and its performance compared with other assets, especially equities, which grew in same period at a rate 7.93% per year without dividend reinvesting (SP500 index). It is interesting to draw comparison here with inflation during this period using CPI, which was 3.95% p.a., meaning that gold delivered a positive real return during this period.

With this fact, and assuming the relationship between M2 and inflation, means that gold offer some protection against inflation, aware of important fact that relationships between M2 and inflation are described in long-term (Fitzgerald, 1999) and need not be valid in short-term period or some particular time cycles (Michl, 2019).

Long-term formula for price of gold from Tab. 4 and Tab. 5:

$$l\_gold_t = -1.17636 + 0.875866\, l\_M2NS_t, \tag{4}$$

$$l\_gold_t = -1.17622 + 0.875849\, l\_M2SL_t. \tag{5}$$

In the model, there were negative constants in the long-run dependence according to Equations (4) and (5). This could be a poor model specification. However, because the M2 level will not fall below the 1971 level, meaning there is no danger of a negative gold price according to the model, leads me to believe it is correct.

Short-term formula for price of gold from Tab. 8 and Tab. 9 using monthly data:

$$\Delta l\_gold_t = 0.735685\, \Delta l\_M2NS_t - 0.0125443\, \hat{u}_{t-1}, \tag{6}$$

$$\Delta l\_gold_t = 1.15047\, \Delta l\_M2SL_t - 0.0126176\, \hat{u}_{t-1}. \tag{7}$$

Comparison of using M2 with seasonally adjusted and not adjusted data in the case of the long-term model did not reveal any significant difference. On the other hand, in case of short-term model, Equations (6) and (7), using seasonally adjusted data provided slightly higher R^2, but Equation (6) using not seasonally adjusted data estimated lower response of change of gold price on change of M2, which seems to me more appropriate.

Short-term formula for price of gold from Tab. 10 and Tab. 11 using semiannual data:

$$\Delta l\_gold_t = 1.03693\ \Delta l\_M2NS_t - 0.0893882\ \hat{u}_{t-1}, \quad (8)$$

$$\Delta l\_gold_t = 1.02477\ \Delta l\_M2SL_t - 0.0894120\ \hat{u}_{t-1}. \quad (9)$$

When using semiannual data in Equations (8) and (9) comparison of using M2 with seasonally adjusted and not adjusted data did not provide any significant difference and higher value of ECT with statistical results in Tab. 10 and Tab. 11 providing better results than monthly data ECM.

5 Conclusion

In the past currencies used to be linked to gold and gold itself served as a currency. Furthermore, gold is used as a reserve in central banks and nowadays is considered as a safe haven and some hedging ability is expected. Other reasons for the demand for gold is also its potential ability to maintain value and to generate returns.

In the period analysed (years 1971–2023) the price of gold grew 7.78% annually, while M2 grew 7% per year and CPI inflation in the US was 3.95% p.a.

This article, then, confirms a long-term relationship between gold price and US M2 using Engle-Granger two-step cointegration.

The short-term EC model using monthly observations validates long-term model, but at a higher significance level (6.6%) which is more than 5% of that usually used and shows very small R^2 on response of growth of gold price depending on growth of M2 per one observed period, in case of this article one month.

The problem was solved by using semiannual data, which explain the short-term relationship between gold price and US M2 at the 5% significance level and statistic tests came out in line with theoretical expectation and being significantly better than in the case of using monthly data. There was no relevant difference found between US M2 in seasonally and not seasonally adjusted versions.

This approach using monthly data can be used to assess the current state of the gold market at a specific moment and whether gold price is under- or overvalued. Such information can be valuable for asset allocation into gold whether performed by retail or institutional type of investor. Assuming some relationship between M2 and inflation, this study can be also beneficial to offset inflation.

For explanation of short-term movement, it is appropriate to use data with less frequent observations. In this study semiannual data was used, which fulfilled all statistical requirements.

The limitation of this approach is that it can be used for long-term position building but is not suitable for market timing or some short-term strategies due to gold price cycles being multi-year. According to Equations (4) and (5), it can be judged whether the price of gold is under or overvalued than it should be according to M2, but is unable to predict the future trajectory and persistence of the trend. This trend can be extended and not reach the equilibrium state for a long time even if, as in Equations (8) and (9), a tendency to return to the equilibrium can be expected by 8.9% in half a year.

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