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An Empirical Study on Impact of Real Interest Rates and Stock Market Volatility on Gold Prices in the US

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ABSTRACT

This study investigates the empirical relationship between real interest rates, stock market volatility, and gold prices. Gold has given a CAGR return of over 8% since year 2000. Gold, often considered a safe-haven asset, tends to exhibit unique price movements in response to macroeconomic variables. Using a dataset spanning 27 years (Jan 1997 to July 2024), this research employs econometric models to analyse how fluctuations in real interest rates and stock market instability influence gold prices. Traditional view is that real interest rates exhibit an inverse relationship with gold prices and heightened stock market volatility is positively correlated with gold prices, suggesting that investors flock to gold during periods of market uncertainty. The results of this study may have important implications for investors, policymakers, and market participants who seek to understand the dynamics between these variables for decision making. The study may also contribute to the broader literature on financial market interconnections by highlighting gold's role as a hedge against both inflation and market turmoil.

Keywords: Volatility, Hedge, Inflation

Introduction

Gold has historically been regarded as a safe-haven asset, particularly during periods of economic uncertainty. Investors often turn to gold when financial markets become volatile or when economic indicators signal instability. Understanding the factors that influence gold prices is critical for both policymakers and market participants. Two key variables that are expected to impact gold prices are **real interest rates** and **stock market volatility**.

A. Real Interest rate

The **real interest rate** is the interest rate that has been adjusted for inflation, providing a more accurate measure of the true cost of borrowing and the real return on investment. It reflects the actual purchasing power of interest earnings or payments after accounting for the erosion of value caused by inflation.

{Real Interest Rate} = {Nominal Interest Rate} – {Inflation Rate}

In the U.S., **TIPS** stands for **Treasury Inflation-Protected Securities**, which are government-issued bonds designed to protect investors from inflation. The **real interest rate** associated with TIPS is particularly important because it reflects the interest rate investors earn after adjusting for inflation.

TIPS directly provide the **real interest rate** because they are structured to account for inflation.

1. **Fixed Real Interest Rate**: The interest (or coupon) rate for TIPS is fixed over the life of the bond, but the principal (the bond's face value) adjusts with inflation. This makes the fixed interest rate a real interest rate, as it does not include inflation.
2. **Inflation Adjustments**: The principal amount in TIPS increases with inflation. Even though the coupon (interest) rate remains fixed, the amount of interest you receive increases as the principal increases.

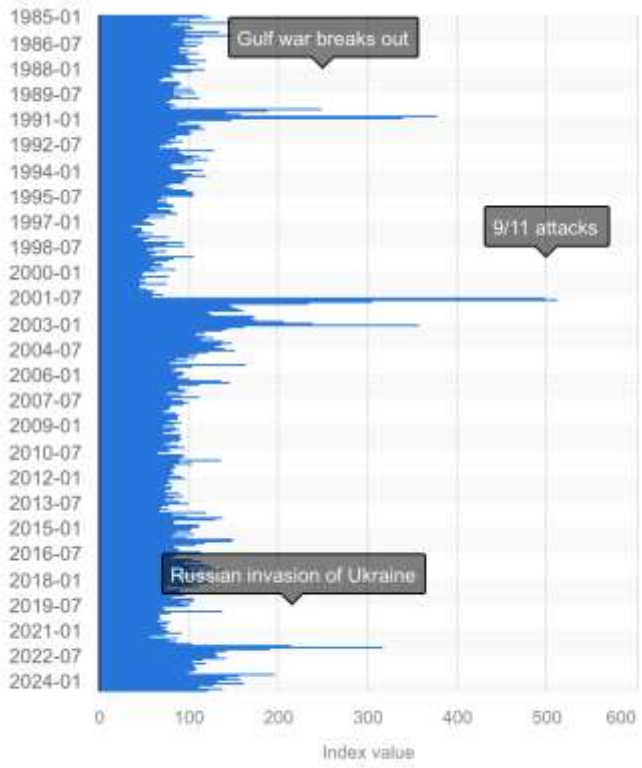
In the context of the U.S. economy, **real interest rates** (interest rates adjusted for inflation) play a crucial role in determining the opportunity cost of holding non-yielding assets like gold. When real interest rates are low or negative, the appeal of holding gold increases, as the cost of forgoing interest-bearing investments diminishes. Conversely, rising real interest rates tend to lower the demand for gold, as investors shift to more lucrative interest-bearing assets.

B. Volatility

The CBOE Volatility Index (VIX) is often referred to as the "fear gauge" of the financial markets. It measures the market's expectation of future volatility over the next 30 days, based on the price of options on the S&P 500 Index. When the VIX rises, it indicates that investors expect more volatility and uncertainty in the stock market, which often coincides with increased fear or risk aversion.

The CBOE Volatility Index (VIX) inherently reflects more than just market volatility—it also captures elements of investor sentiment, fear, and uncertainty, including factors like geopolitical turmoil and behavioural responses to risk. Low VIX (typically below 20) suggests that markets are stable, and investors are not overly concerned about future volatility. High VIX (typically above 30) indicates heightened uncertainty or fear, suggesting that market participants expect significant volatility in the near future. VIX also is a Market Sentiment Indicator as when the VIX rises, it reflects growing concern over potential downturns or market instability. It often spikes during times of financial stress, economic crises, geopolitical tensions, or unexpected macroeconomic events.

Global Geopolitical Risk (GPR) and the Volatility Index (VIX) are both important indicators in financial markets and they measure varied aspects of market uncertainty. Geopolitical risks (such as wars, terrorist attacks, and political instability) often lead to increased market uncertainty, causing investors to become more risk averse. This uncertainty is frequently priced into the VIX as a reflection of expected volatility. They can be correlated, especially during periods of heightened uncertainty and risk aversion. What GPR index alludes gets captured in the liquid VIX which is heavily traded instrument. Thus, VIX can be a used as a good proxy for geopolitical risks as well.



(Chart 1: GPR index)

A rise in the VIX is closely related to the **demand for safe-haven assets**. Safe-haven assets are investments that are expected to retain or increase in value during times of market turbulence. These assets include- Gold, Japanese Yen, Swiss Franc, US treasuries etc. This flight-to-safety phenomenon alludes to the inverse relationship between stock market volatility and gold prices.

This empirical study aims to investigate the impact of U.S. real interest rates and stock market volatility on gold prices. By using time-series data, the study will explore the relationships between these variables and determine the extent to which changes in real interest rates and stock market volatility influence fluctuations in gold prices. Understanding these dynamics will provide valuable insights into how investors can use gold as part of their portfolio management strategies during times of financial uncertainty.

Literature Review, Research gap and Objectives

Batten, J. A., & Ciner, C. (2013) worked on the economic determinants of gold returns. In this study, Batten and Ciner investigate the economic determinants of gold returns. They explore the impact of various macroeconomic factors such as inflation, exchange rates, and interest rates on the returns of gold. The research provides valuable insights into the factors driving gold prices and its role as a safe-haven asset and inflation hedge. Research by Batten and Ciner (2013) highlighted the importance of considering different inflation regimes and time horizons when assessing gold's effectiveness as a

hedge against inflation. Batten and Ciner use econometric models to analyse time-series data, focusing on periods of market stress to assess gold's behaviour. Their empirical work involved data from multiple countries, allowing them to evaluate how gold performs not only in U.S. markets but also globally.

The financialization of gold markets, including the proliferation of gold ETFs and derivative products, has transformed the dynamics of gold pricing and trading. Erb and Harvey (2013) argued that financialization may have diluted gold's inflation-hedging properties, as speculative trading and short-term dynamics increasingly influence gold prices. The evolving structure of gold markets and the integration of gold into financial portfolios have implications for its effectiveness as an inflation hedge. Erb and Harvey suggest that gold's value as an inflation hedge is not as strong as commonly believed, especially in the short term. Instead, they argue that gold's price movements are driven by investor sentiment and other factors beyond inflation.

The study by Baur and Lucey (2010) titled "Is Gold a Hedge or a Safe Haven? An Analysis of Stocks, Bonds and Gold" explores gold's role as both a hedge and a safe haven asset. The research distinguished between these two concepts and provides empirical evidence on how gold behaves in different market conditions. The study finds that gold generally acts as a hedge against inflation and equity market declines over the long term. This means that during normal market conditions, gold maintains its value or appreciates, offering protection against inflation and stock market losses. Baur and Lucey used daily data from stock and bond markets to test the role of gold across different time horizons and market conditions. They analysed how gold prices moved relative to stock and bond returns, particularly during periods of high volatility and financial stress.

Worthington and Pahlavani's 2007 study titled "Gold Investment as an Inflation Hedge: Cointegration Evidence with Allowance for Endogenous Structural Breaks" focuses on the long-term relationship between gold prices and inflation in the U.S. economy. The study found a long-term equilibrium relationship between gold prices and inflation, suggesting that gold serves as a hedge against inflation. However, the strength of gold's role as an inflation hedge varied across different time periods, particularly when accounting for structural breaks in the data. The study concludes that while gold can act as a reliable inflation hedge in the long term, it is not always effective in the short term, where other factors may influence gold prices

Literature review summary

Year	**Author**	**Data and Methodology**	**Major findings**
2005	Erb & Harvey	Used historical gold prices and macroeconomic data. Examined the relationship between real interest rates, inflation, and gold. Analysed long-term performance of gold	Gold prices are inversely related to real interest rates. Gold's inflation-hedging properties are more prominent in the long term. Gold offers low real returns long-term
2011	Batten and Ciner	Used time-series data on gold prices, oil prices, and stock indices. Employed Granger causality tests and vector autoregression (VAR) models to assess relationships	Gold has a safe-haven role, especially during stock market downturns. Gold exhibits significant causal relations with oil and stock markets, particularly in turbulent periods
2010	Baur and Lucey	Analysed data from global financial markets. Applied econometric models (e.g., quantile regressions) to measure gold's safe-haven and hedge properties against stocks and bonds	Gold acts as a hedge against stocks in normal market conditions. During extreme market downturns, gold behaves as a safe-haven asset, protecting against market crashes
2007	Worthington and Pahlavani	Utilized data from 1945 to 2006 to assess the long-term relationship between gold prices and inflation in the U.S. Applied cointegration techniques and error correction models	Found a long-term equilibrium relationship between gold prices and inflation. Gold serves as a hedge against inflation, but the relationship may vary across different periods
2006	Levin, Montagnoli & Wright	Analysed the interaction between gold prices and macroeconomic indicators, including real interest rates and inflation expectations. Used econometric models and regression analysis	Confirmed gold's role as a hedge against inflation expectations. Found that real interest rates have a significant impact on gold prices, influencing investor demand for gold

While many studies have been done on determining the factors affecting gold price, this empirical analysis uses traded real interest rate (like TIPS) to study its impact. Past studies focused on studying the risk free rate (r) derived from treasury bonds whereas focus of this study is to strip inflation out of risk free rate and study its role in predicting gold prices. Any traded instrument itself factors in behavioural dynamics which will also be part of the study implicitly. With the advent of technology, AI, speculation has become more prominent and arbitrages have come down. Financial markets have become more and more liquid and with the US Fed's stance of pumping liquidity post COVID 19, trading volumes have gone up in financial instruments. Speculative or hedging positions can be taken in a split of a second and thus reflects the market sentiment at any point in time.

The endeavour of this study is to study the factors that impact gold prices using highly liquid traded instruments like TIPS, VIX etc

Objectives

a. To analyse whether real interest rates, as measured by Treasury Inflation-Protected Securities (TIPS), affect (both in terms of quantum and direction) the price of gold over time

b. To determine if increased market volatility leads to higher gold prices, indicating efficacy of gold's role as an inflation hedge in turbulent times.

Research Methodology

a. Research Design

This study will employ a quantitative research design using empirical analysis, focusing on assessing the relationships between variables using statistical techniques. The study will adopt a causal-comparative approach to examine how changes in real interest rates (TIPS yield) and stock market volatility (CBOE VIX) influence gold prices (XAU).

b. Data Collection

27 years of time series data from January 1997 to July 2024 for the following variables to include various economic conditions and events such as LTCM failure, Dotcom bubble, GFC, Covid etc.

Gold Prices: Monthly historical gold prices (in USD per ounce) collected from financial databases such as Bloomberg.

Real Interest Rates: Monthly closing yield on US 10year TIPS obtained from Bloomberg.

Volatility: Monthly closing CBOE VIX data sourced from Chicago Board Options Exchange.

c. Statistical Analysis

Unit root test

Stationarity Check- Conduct tests (e.g., Augmented Dickey-Fuller (ADF) test) to check for stationarity of the time series data. If any series is found to be non-stationary, appropriate transformations (such as differencing or logarithmic transformations) will be applied to achieve stationarity.

Descriptive Statistics- Calculate descriptive statistics (mean, median, standard deviation, etc.) for each variable to understand their distributions.

- Model Specification: The following regression model will be specified:

$XAU_t = ß0 + ß1 \times TIPS_t + ß2 \times VIX_t + ß3 \times (Control)_t + epsilon_t$

Estimation Method: Use multiple linear regression analysis to estimate the coefficients of the model. The analysis will assess the impact of real interest rates, stock market volatility, and control variables on gold prices.

Hypothesis

i. H0 (Null Hypothesis): There is no significant relationship between TIPS yield, and gold prices, after controlling for other factors.

$H0: ß1 = 0$

where ß1 is the coefficient of TIPS in the regression model

ii. H0 (Null Hypothesis): There is no significant relationship between the CBOE VIX and gold prices (XAU).

$H0: ß2 = 0$

where ß2 is the coefficient of VIX in the regression model.

Significance Level: Use a significance level of 0.05 to determine whether to reject the null hypotheses.

Analysis

Unit root test- Augmented Dickey Fuller test (Stationarity Check)

Nonstationary in time series data occurs when the statistical properties (mean, variance, autocorrelation) of the series change over time. This can make it difficult to model or forecast effectively.

The time series data of variables were tested for stationarity using the graphical plot as well as using the unit root test using Augmented Dickey Fuller test. The graphical plots of the explanatory variables (10year TIPS and CBOE VIX) and response variable (XAU) alluded to that XAU data series as well

as TIPS data series were not stationary due to non-consistent mean. The same was confirmed using the ADF (Annex 2). However, the variable CBOE VIX was found to be stationary.

Stationarity checks on variables

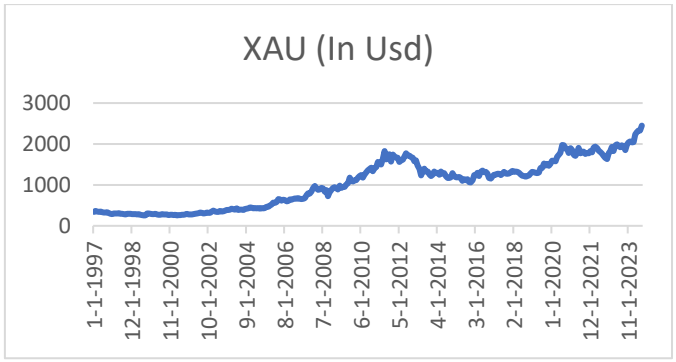


Chart 2: Gold prices

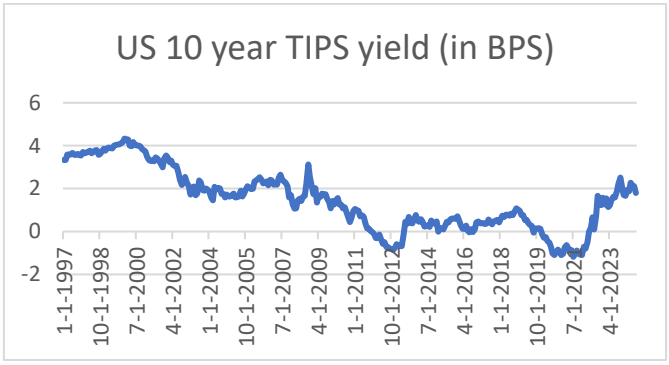


Chart 3: 10 year TIPS (in bps)

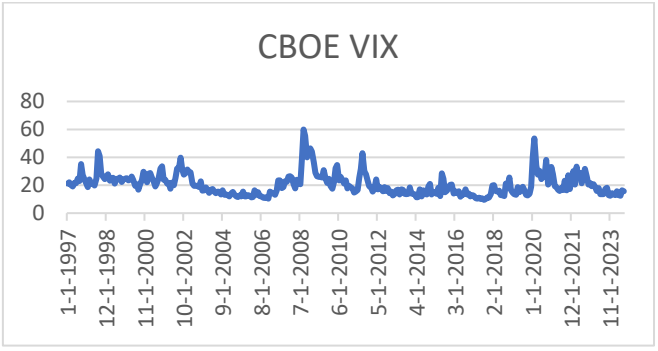


Chart 4: CBOE VIX

Interpretation of ADF test statistics without transformation:

Variable	p-value	t-statistics <critical value	t-statistics> critical value	Interpretation
XAU	0.9867 (>0.05)	No	Yes	Nonstationary
TIPS	0.4549 (>0.05)	No	Yes	Nonstationary
CBOE VIX	0.0000 (<0.05)	Yes	No	Stationary

Table 1: Interpretation of ADF test statistics without transformation

To make the time series stationary for XAU and TIPS, differential transformations were carried out for XAU and TIPS as under

$Y't = Y_t - Y_{t-1}$

ADF statistics confirmed the stationarity of the data post transformation as shown in tables below

Augmented Dickey-Fuller (ADF) Test Results post transformation:

	ADF statistics	p-value	Critical Values
Delta XAU	-20.28	0.0	1%: -3.45
			5%: -2.87
			10%: -2.57

Table 2: Interpretation of ADF test statistics after transformation for XAU

Conclusion: Since the ADF statistic (-20.28) is much lower than the critical values at all levels (1%, 5%, and 10%), and the p-value is 0, we reject the null hypothesis of the presence of a unit root. This indicates that the differenced XAU series is **stationary**.

	ADF statistics	p-value	Critical Values
Delta TIPS	-14.01	3.76 e -26	1%: -3.45
			5%: -2.87
			10%: -2.57

Table 3: Interpretation of ADF test statistics after transformation for TIPS

Conclusion: The ADF statistic (-14.01) is much lower than the critical values, and the p-value is extremely small. We reject the null hypothesis, meaning the differenced TIPS series is **stationary**.

	ADF statistics	p-value	Critical Values
CBOE VIX	-6.06	1.22 e -07	1%: -3.45
			5%: -2.87
			10%: -2.57

Table 4: Interpretation of ADF test statistics without transformation for CBOE VIX

Conclusion: The ADF statistic (-6.06) is also lower than the critical values, and the p-value is very small. We reject the null hypothesis, indicating that the VIX series is **stationary**.

Multi Variable Regression

Post transformation, the model equation becomes as under

Δ (XAU_t)= ß0 + ß1 x Δ (TIPS_t) + ß2 x VIX_t + ε_t

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.41125977
R Square	0.1691346
Adjusted R Square	0.16405286
Standard Error	49.9066317
Observations	330

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	2	165792.952	82896.476	33.2827766	6.9705E-14
Residual	327	814449.706	2490.67188		
Total	329	980242.658			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	3.52839827	7.64497417	0.46153175	0.64472401	-11.51114	18.5679363	-11.51114	18.5679363
Δ (TIPS)	-104.32857	12.8222966	-8.136496	8.5841E-15	-129.55317	-79.103965	-129.55317	-79.103965
CBOE VIX (USD)	0.11520532	0.34846834	0.33060484	0.74115472	-0.5703173	0.80072796	-0.5703173	0.80072796

Table 5: Multivariable regression statistics

i. The Multiple R value indicates the correlation between the observed and predicted values of the dependent variable (XAU). A value of 0.4112 suggests a moderate positive correlation, meaning that as the independent variables (TIPS and VIX) change, the dependent variable (XAU) tends to change in the same direction

ii. The coefficient for Δ (TIPS) is **-104.3286**, indicating that a one percentage (100 bps) increase in the Δ TIPS (real rate) is associated with a decrease of approximately USD **104.33** in the ΔGold price, holding the CBOE VIX constant.

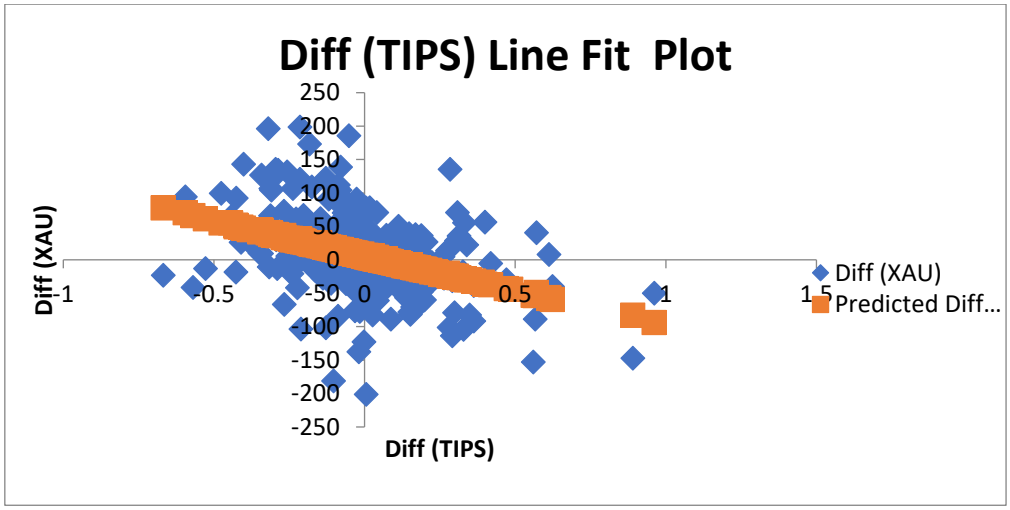
iii. The p-value (8.5841E-15) is significantly less than 0.05, indicating that this relationship is **statistically significant**. It can be confidently inferred that the change in Real rates has a substantial negative impact on the change in Gold prices.

iv. The coefficient for CBOE VIX is **0.1152**, suggesting that a one-unit increase in the CBOE VIX is associated with an increase of approximately **0.1152** units in the dependent variable, holding the change in TIPS constant. However, this effect is quite small.

v. The p-value (0.7412) is significantly higher than 0.05, indicating that the VIX does **not have a statistically significant impact** on the Δ Gold prices. Thus, it cannot be concluded that changes in the VIX meaningfully affect the dependent variable.

The regression analysis reveals that changes in TIPS have a significant negative effect on the dependent variable, while the VIX does not have a significant impact.

Δ (XAU) = 3.5284 - 104.3286 x Δ (TIPS) + 0.1152 x (CBOE VIX) + ε



Interpretation

a. The negative relationship between real interest rates (TIPS) and the gold prices is because higher real interest rates decrease the attractiveness of non-yielding assets such as gold. When real rates rise, the opportunity cost of holding gold increases, leading to lower demand and prices for gold or other similar assets.

b. TIPS are designed to protect against inflation by adjusting the principal based on inflation rates. A fall in TIPS real rates typically indicates that inflation expectations are stable or increasing, since TIPS yields reflect real, inflation-adjusted returns. When inflation expectations rise, the demand of gold rises. Thus, the study also reflects that "hedge effectiveness of gold against inflation" is very much intact.

c. Investor behaviour explains the strong inverse relationship between real rates and gold prices. Rising real interest rates make government bonds and other interest-yielding assets more appealing to investors seeking returns. This reduces the relative attractiveness of gold, which serves primarily as a store of value rather than a source of income.

d. Another channel through which Central banks impact gold is via Monetary policy and has been a dominant factor affecting gold prices. Monetary policy responses target real interest rates in the economy. Loose monetary policies (e.g., quantitative easing, low-interest rates) tend to weaken currencies and raise inflation expectations, which is bullish for gold as investors seek alternatives to fiat currencies.

e. The inclusion of the VIX in the model has not captured its impact adequately as the relationship is non-linear or influenced by other external variables not included in the analysis. One possible explanation for this is that Central banks are the biggest market players in gold market and any Central bank activity in Gold may not have impact on CBOE VIX but will impact the gold prices. Thus, while it is a widely accepted measure of market volatility, it may not directly affect the dependent variable (XAU) without considering additional factors such as market trends, Central Bank activity.

f. Lack of predictive power- The VIX does not meaningfully explain or predict changes in XAU (gold prices) in the context of this model. Although the coefficient for VIX exists, its impact on gold prices is not strong enough to be considered reliable. In other words, changes in market volatility (as measured by VIX) are not strongly associated with changes in gold prices.

g. Lag effect- The insignificance of VIX could indicate that the relationship between stock market volatility and gold prices may not be linear or immediate. For instance, VIX might affect gold prices with a time lag or through non-linear dynamics, which a simple linear regression model might not capture. More advanced modelling (e.g., time-series models or non-linear approaches) might be needed to explore these possibilities.

Discussion and Challenges

a. Using real interest rates as derived from TIPS presents some challenges in the study. TIPS yields are directly tied to inflation expectations, and changes in these expectations can influence real interest rates. However, inflation data often has a reporting lag, which can introduce noise when studying the relationship with gold prices.

b. Investor behaviour and risk perception also plays a very big role, and these dynamics can obscure the impact of real interest rates, making it difficult to isolate their effect.

c. Forward Guidance by US Fed on future rate changes quickly gets priced in real interest rates (through TIPS yields) as the market is very liquid, but gold prices may react less quickly to forward guidance than to actual rate changes.

d. Term structure of TIPS- Yield curve inversions (short-term rates are higher than long-term rates), also make it difficult to interpret the relationship between real interest rates and gold. Short end yields are also a function of liquidity and central banks operations which further complicates the relationship.

e. Other factors which complicate the dynamics between real rates and gold is the Central Bank's gold purchases especially during rising rates scenario. As rates are rising, demand for gold drops as bonds offer good risk-free interest but Central Bank's purchase of Gold will increase demand for gold.

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Annex 1

	Response	Explanatory	Explanatory
Date	**XAU (In Usd)**	**US 10 year TIPS yield (in BPS)**	**CBOE VIX (USD)**
1/31/1997	344.6	3.34	21.1
2/28/1997	363.7	3.34	22.14
3/31/1997	351.5	3.58	20.06
4/30/1997	339.75	3.58	19.19
5/30/1997	344.9	3.58	21.53
6/30/1997	334.2	3.66	21.48
7/31/1997	324.8	3.57	24.76
8/29/1997	324.4	3.57	22.91
9/30/1997	334.7	3.61	35.09
10/31/1997	311.7	3.55	27.43
11/28/1997	297.2	3.54	24.01
12/31/1997	289.3	3.71	21.47
1/30/1998	302.7	3.64	18.55
2/27/1998	299.4	3.68	24.22
3/31/1998	301.2	3.72	21.18
4/30/1998	306.9	3.76	21.32
5/29/1998	293.2	3.64	19.71
6/30/1998	297.2	3.71	24.8
7/31/1998	286.7	3.78	44.28
8/31/1998	275.8	3.8	40.95
9/30/1998	297.2	3.57	28.05
10/30/1998	292.8	3.62	26.01
11/30/1998	293.4	3.73	24.42
12/31/1998	288.5	3.85	26.25
1/29/1999	286.4	3.77	27.88
2/26/1999	287.3	3.88	23.26
3/31/1999	280.3	3.92	25.07
4/30/1999	286.8	3.88	25.39
5/31/1999	270.8	3.87	21.09
6/30/1999	262.75	4.01	24.64
7/30/1999	256.2	4.04	24.45
8/31/1999	255.8	4.05	25.41
9/30/1999	299	4.07	22.2
10/29/1999	300.2	4.11	24.18
11/30/1999	290.95	4.15	24.64
12/31/1999	288.75	4.33	24.95
1/31/2000	283.9	4.3	23.37
2/29/2000	292.7	4.29	24.11
3/31/2000	279.45	4	26.2
4/28/2000	273.85	3.97	23.65
5/31/2000	272.6	4.17	19.54
6/30/2000	289.3	4.07	20.74
7/31/2000	277.5	4.01	16.84
8/31/2000	278.2	4	20.57
9/29/2000	274.75	3.97	23.63
10/31/2000	265.4	3.85	29.65
11/30/2000	270.7	3.8	26.85
12/29/2000	272.5	3.73	22.02
1/31/2001	266.1	3.505	28.35
2/28/2001	267.4	3.339	28.64
3/30/2001	258.2	3.289	25.48
4/30/2001	264.3	3.312	22.64
5/31/2001	266.1	3.267	19.06
6/29/2001	271.1	3.448	21.62
7/31/2001	267.15	3.395	24.92
8/31/2001	274.65	3.296	31.93
9/28/2001	293.5	3.138	33.56
10/31/2001	279.9	2.988	23.84
11/30/2001	274.65	3.407	23.8
12/31/2001	279.2	3.543	21.09
1/31/2002	282.8	3.431	21.59
2/28/2002	296.8	3.222	17.4
3/29/2002	303.15	3.311	21.91
4/30/2002	308.7	3.108	19.98
5/31/2002	326.8	3.054	25.4
6/28/2002	314.7	3.067	32.03
7/31/2002	303.8	2.751	32.64
8/30/2002	313	2.409	39.69
9/30/2002	323.8	2.177	31.14
10/31/2002	318	2.394	27.5
11/29/2002	318.4	2.548	28.62
12/31/2002	348.3	2.255	31.17
1/31/2003	368.4	2.144	29.63
2/28/2003	350.2	1.717	29.15

3/31/2003	337.7	1.952	21.21
4/30/2003	338.8	2.096	19.47
5/30/2003	364.7	1.686	19.52
6/30/2003	346.65	1.77	19.49
7/31/2003	354.6	2.382	18.63
8/29/2003	375.8	2.282	22.72
9/30/2003	385.6	1.935	16.1
10/31/2003	384.75	1.9	16.32
11/28/2003	398.25	2.013	18.31
12/31/2003	415.3	1.949	16.63
1/30/2004	402.7	1.845	14.55
2/27/2004	396.4	1.576	16.74
3/31/2004	427	1.453	17.19
4/30/2004	387	2.0767	15.5
5/31/2004	395.8	1.9677	14.34
6/30/2004	394.5	2.0362	15.32
7/30/2004	391.3	2.0034	15.29
8/31/2004	410.1	1.7592	13.34
9/30/2004	418.5	1.7453	16.27
10/29/2004	428.8	1.5952	13.24
11/30/2004	451.25	1.7257	13.29
12/31/2004	438.8	1.627	12.82
1/31/2005	423	1.6352	12.08
2/28/2005	436	1.7009	14.02
3/31/2005	428.7	1.7698	15.31
4/29/2005	434.8	1.5935	13.29
5/31/2005	417.6	1.6021	12.04
6/30/2005	435.6	1.6374	11.57
7/29/2005	430.2	1.894	12.6
8/31/2005	435.6	1.6391	11.92
9/30/2005	469.5	1.7597	15.32
10/31/2005	465.5	1.9833	12.06
11/30/2005	493.36	2.1129	12.07
12/30/2005	518	2.0526	12.95
1/31/2006	569.3	1.9808	12.34
2/28/2006	562	1.9964	11.39
3/31/2006	584.1	2.3356	11.59
4/28/2006	654.85	2.3767	16.44
5/31/2006	645.6	2.4564	13.08
6/30/2006	616.2	2.5305	14.95
7/31/2006	637.5	2.4023	12.31
8/31/2006	627.8	2.2374	11.98
9/29/2006	598.8	2.2707	11.1
10/31/2006	607.1	2.328	10.91
11/30/2006	648.5	2.1477	11.56
12/29/2006	637.21	2.4023	10.42
1/31/2007	653.7	2.382	15.42
2/28/2007	669.7	2.1857	14.64
3/30/2007	664.3	2.2001	14.22
4/30/2007	678.7	2.1845	13.05
5/31/2007	660.76	2.5109	16.23
6/29/2007	650.4	2.6472	23.52
7/31/2007	664.7	2.4119	23.38
8/31/2007	673.8	2.336	18
9/28/2007	744	2.2688	18.53
10/31/2007	797.37	2.113	22.87
11/30/2007	784.1	1.5858	22.5
12/31/2007	834.1	1.6984	26.2
1/31/2008	926.5	1.2729	26.54
2/29/2008	974.3	1.068	25.61
3/31/2008	917.3	1.0835	20.79
4/30/2008	878.55	1.4466	17.83
5/30/2008	887.5	1.532	23.95
6/30/2008	926	1.4246	22.94
7/31/2008	914.8	1.6379	20.65
8/29/2008	832.03	1.6645	39.39
9/30/2008	872.45	2.2359	59.89
10/31/2008	725.22	3.127	55.28
11/28/2008	819.42	2.5322	40
12/31/2008	883.42	2.0886	44.84
1/30/2009	929.35	1.7437	46.35
2/27/2009	943.2	2.0197	44.14
3/31/2009	920.13	1.3523	36.5
4/30/2009	888.87	1.6442	28.92
5/29/2009	979.8	1.618	26.35
6/30/2009	927.12	1.764	25.92
7/31/2009	954.63	1.7052	26.01
8/31/2009	951.75	1.74	25.61
9/30/2009	1008.1	1.5316	30.69
10/30/2009	1046	1.366	24.51
11/30/2009	1180.05	1.0796	21.68
12/31/2009	1097.35	1.4281	24.62

1/29/2010	1081.7	1.2644	19.5
2/26/2010	1118.08	1.4533	17.59
3/31/2010	1113.6	1.565	22.05
4/30/2010	1179.4	1.2531	32.07
5/31/2010	1216.6	1.2453	34.54
6/30/2010	1242.75	1.0777	23.5
7/30/2010	1181.5	1.1202	26.05
8/31/2010	1247.8	0.9181	23.7
9/30/2010	1308.98	0.691	21.2
10/29/2010	1359.8	0.4462	23.54
11/30/2010	1386.55	0.651	17.75
12/31/2010	1422	0.9645	19.53
1/31/2011	1333.05	1.0521	18.35
2/28/2011	1411.7	1.01	17.74
3/31/2011	1432.5	0.9624	14.75
4/29/2011	1564.1	0.7061	15.45
5/31/2011	1536.15	0.7547	16.52
6/30/2011	1500.58	0.6934	25.25
7/29/2011	1627.45	0.3516	31.62
8/31/2011	1826.1	0.1379	42.96
9/30/2011	1624.6	0.1439	29.96
10/31/2011	1715.2	0.0252	27.8
11/30/2011	1746.75	-0.0222	23.4
12/30/2011	1565.42	-0.1243	19.44
1/31/2012	1738.57	-0.3068	18.43
2/29/2012	1697.07	-0.3034	15.5
3/30/2012	1668.81	-0.139	17.15
4/30/2012	1665.2	-0.3571	24.06
5/31/2012	1561.43	-0.5677	17.08
6/29/2012	1598.2	-0.4951	18.93
7/31/2012	1615.15	-0.7235	17.47
8/31/2012	1692.6	-0.7175	15.73
9/28/2012	1773.25	-0.7949	18.6
10/31/2012	1721	-0.8139	15.87
11/30/2012	1715.55	-0.8556	18.02
12/31/2012	1676.1	-0.7513	14.28
1/31/2013	1664.2	-0.5837	15.51
2/28/2013	1579.94	-0.6717	12.7
3/29/2013	1600	-0.6729	13.52
4/30/2013	1477	-0.6749	16.3
5/31/2013	1388.3	-0.1077	16.86
6/28/2013	1235.4	0.4526	13.45
7/31/2013	1325.49	0.367	17.01
8/30/2013	1396.04	0.6751	16.6
9/30/2013	1329.32	0.4092	13.75
10/31/2013	1323.21	0.3824	13.7
11/29/2013	1255.1	0.5613	13.72
12/31/2013	1213.58	0.7648	18.41
1/31/2014	1244.65	0.5105	14
2/28/2014	1326.56	0.4588	13.88
3/31/2014	1284.16	0.5757	13.41
4/30/2014	1291.72	0.4545	11.4
5/30/2014	1249.78	0.2314	11.57
6/30/2014	1327.46	0.2485	16.95
7/31/2014	1282.71	0.2883	11.98
8/29/2014	1287.62	0.2139	16.31
9/30/2014	1208.29	0.5134	14.03
10/31/2014	1173.08	0.4021	13.33
11/28/2014	1168.16	0.359	19.2
12/31/2014	1184.68	0.4689	20.97
1/30/2015	1284.07	-0.0067	13.34
2/27/2015	1213.37	0.1535	15.29
3/31/2015	1183.77	0.1423	14.55
4/30/2015	1184.52	0.0979	13.84
5/29/2015	1190.8	0.2937	18.23
6/30/2015	1172.55	0.4553	12.12
7/31/2015	1096	0.424	28.43
8/31/2015	1135.08	0.5723	24.5
9/30/2015	1115.25	0.5997	15.07
10/30/2015	1142.16	0.6067	16.13
11/30/2015	1064.93	0.5908	18.21
12/31/2015	1061.29	0.701	20.2
1/29/2016	1118.31	0.5145	20.55
2/29/2016	1238.72	0.3003	13.95
3/31/2016	1232.8	0.1324	15.7
4/29/2016	1293.6	0.1219	14.19
5/31/2016	1215.43	0.2718	15.63
6/30/2016	1322	0.0343	11.87
7/29/2016	1351.4	-0.0418	13.42
8/31/2016	1309.09	0.1059	13.29
9/30/2016	1316.56	-0.0234	17.06
10/31/2016	1277.47	0.091	13.33

11/30/2016	1173.39	0.4202	14.04
12/30/2016	1153	0.4741	11.99
1/31/2017	1210.98	0.3926	12.92
2/28/2017	1248.79	0.3766	12.37
3/31/2017	1250.26	0.3986	10.82
4/28/2017	1269.51	0.3529	10.41
5/31/2017	1269.03	0.3733	11.18
6/30/2017	1242.27	0.5638	10.26
7/31/2017	1269.65	0.4748	10.59
8/31/2017	1321.56	0.342	9.51
9/29/2017	1281.98	0.4764	10.18
10/31/2017	1271.95	0.4922	11.28
11/30/2017	1275.87	0.5377	11.04
12/29/2017	1307.8	0.4219	13.54
1/31/2018	1345.4	0.5915	19.85
2/28/2018	1318.75	0.74	19.97
3/30/2018	1325.73	0.681	15.93
4/30/2018	1315.54	0.7762	15.43
5/31/2018	1298.7	0.7761	16.09
6/29/2018	1257.9	0.7328	12.83
7/31/2018	1224.3	0.8303	12.86
8/31/2018	1217.06	0.7681	12.12
9/28/2018	1200.36	0.9139	21.23
10/31/2018	1214.83	1.0798	18.07
11/30/2018	1234.68	1.0193	25.42
12/31/2018	1283.24	0.9692	16.57
1/31/2019	1321.4	0.7639	14.7
2/28/2019	1313.45	0.7688	13.71
3/29/2019	1292.5	0.5282	13.12
4/30/2019	1283.67	0.5506	18.71
5/31/2019	1305.8	0.3814	15.08
6/28/2019	1409.75	0.3005	16.12
7/31/2019	1413.98	0.2619	18.98
8/30/2019	1520.58	-0.0486	16.24
9/30/2019	1472.79	0.1415	13.22
10/31/2019	1513.24	0.1373	12.62
11/29/2019	1464.35	0.1518	13.78
12/31/2019	1517.6	0.1296	18.84
1/31/2020	1590.03	-0.1378	40.11
2/28/2020	1586.61	-0.2859	53.54
3/31/2020	1578.92	-0.2601	34.15
4/30/2020	1687.86	-0.4354	27.51
5/29/2020	1731.22	-0.5111	30.43
6/30/2020	1781.49	-0.7102	24.46
7/31/2020	1977.57	-1.0293	26.41
8/31/2020	1968.09	-1.1039	26.37
9/30/2020	1886.26	-0.9515	38.02
10/30/2020	1879.2	-0.8362	20.57
11/30/2020	1777.33	-0.964	22.75
12/31/2020	1899.08	-1.092	33.09
1/29/2021	1848.4	-1.0379	27.95
2/26/2021	1734.89	-0.7461	19.4
3/31/2021	1707.94	-0.6363	18.61
4/30/2021	1769.58	-0.7823	16.76
5/31/2021	1908	-0.8618	15.83
6/30/2021	1770.37	-0.88	18.24
7/30/2021	1814.52	-1.1798	16.48
8/31/2021	1814.01	-1.0314	23.14
9/30/2021	1757.27	-0.8916	16.26
10/29/2021	1783.74	-1.0366	27.19
11/30/2021	1774.93	-1.0876	17.22
12/31/2021	1829.95	-1.1033	24.83
1/31/2022	1797.56	-0.712	30.15
2/28/2022	1909.43	-0.7991	20.56
3/31/2022	1937.93	-0.4934	33.4
4/29/2022	1897.44	-0.0078	26.19
5/31/2022	1837.56	0.1914	28.71
6/30/2022	1807.52	0.6626	21.33
7/29/2022	1766.35	0.0934	25.87
8/31/2022	1711.27	0.7063	31.62
9/30/2022	1661.02	1.6685	25.88
10/31/2022	1633.73	1.5309	20.58
11/30/2022	1768.83	1.2356	21.67
12/30/2022	1824.26	1.5672	19.4
1/31/2023	1928.57	1.259	20.7
2/28/2023	1827.1	1.54	18.7
3/31/2023	1969.83	1.1393	15.78
4/28/2023	1990.4	1.2105	17.94
5/31/2023	1963	1.4745	13.59
6/30/2023	1919.66	1.614	13.63
7/31/2023	1965.58	1.5827	13.57
8/31/2023	1940.59	1.8658	17.52

9/29/2023	1849	2.2286	18.14
10/31/2023	1984.4	2.5124	12.92
11/30/2023	2036.74	2.0871	12.45
12/29/2023	2063.39	1.7056	14.35
1/31/2024	2040.03	1.6645	13.4
2/29/2024	2044.67	1.9253	13.01
3/29/2024	2230.3	1.8736	15.65
4/30/2024	2286.65	2.2737	12.92
5/31/2024	2328.02	2.1466	12.44
6/28/2024	2327.23	2.107	16.36
7/31/2024	2448.26	1.7992	15.55

Annex 2

Augmented Dickey Fuller Test

SER01: XAU

Null Hypothesis: SER01 has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=16)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		0.503133	0.9867
Test critical values:	1% level	-3.449977	
	5% level	-2.870084	
	10% level	-2.571391	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(SER01)
Method: Least Squares
Date: 10/01/24 Time: 17:39
Sample (adjusted): 1997M02 2024M07
Included observations: 330 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
SER01(-1)	0.002592	0.005151	0.503133	0.6152
C	3.727039	6.061527	0.614868	0.5391

R-squared	0.000771	Mean dependent var	6.374727
Adjusted R-squared	-0.002275	S.D. dependent var	54.58444
S.E. of regression	54.64650	Akaike info criterion	10.84569
Sum squared resid	979486.7	Schwarz criterion	10.86871
Log likelihood	-1787.539	Hannan-Quinn criter.	10.85487
F-statistic	0.253143	Durbin-Watson stat	2.232212
Prob(F-statistic)	0.615209		

SER02: US TIPS

Null Hypothesis: SER02 has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=16)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.651794	0.4549
Test critical values:	1% level	-3.449977	
	5% level	-2.870084	
	10% level	-2.571391	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(SER02)
Method: Least Squares
Date: 10/01/24 Time: 17:40
Sample (adjusted): 1997M02 2024M07
Included observations: 330 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
SER02(-1)	-0.013442	0.008138	-1.651794	0.0995
C	0.014855	0.016693	0.889876	0.3742

R-squared	0.008250	Mean dependent var	-0.004669
Adjusted R-squared	0.005226	S.D. dependent var	0.214702
S.E. of regression	0.214140	Akaike info criterion	-0.238327
Sum squared resid	15.04081	Schwarz criterion	-0.215302
Log likelihood	41.32400	Hannan-Quinn criter.	-0.229143
F-statistic	2.728424	Durbin-Watson stat	1.966397
Prob(F-statistic)	0.099533		

SER03: CBOE VIX

Null Hypothesis: SER03 has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=16)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.059359	0.0000
Test critical values:	1% level	-3.449977	
	5% level	-2.870084	
	10% level	-2.571391	

*MacKinnon (1996) one-sided p-values.

Augmented Dickey-Fuller Test Equation
Dependent Variable: D(SER03)
Method: Least Squares
Date: 10/01/24 Time: 17:44
Sample (adjusted): 1997M02 2024M07
Included observations: 330 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
SER03(-1)	-0.201923	0.033324	-6.059359	0.0000
C	4.121611	0.731767	5.632411	0.0000

R-squared	0.100670	Mean dependent var	-0.016818
Adjusted R-squared	0.097928	S.D. dependent var	5.024823
S.E. of regression	4.772450	Akaike info criterion	5.969639
Sum squared resid	7470.619	Schwarz criterion	5.992664
Log likelihood	-982.9904	Hannan-Quinn criter.	5.978823
F-statistic	36.71583	Durbin-Watson stat	2.024931
Prob(F-statistic)	0.000000		