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Domestic macroeconomic determinants of precious metals prices in developed and emerging economies: An international analysis of the long and short run

Hafiz Muhammad Usman Rana [a], Fergal O'Connor [b,*]

[a] Birmingham City Business School, United Kingdom
[b] Cork University Business School, Ireland

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ABSTRACT

This study examines the relationship between domestic macroeconomic factors and domestic precious metals prices across developed and emerging markets from 1979 to 2020. The statistical characteristics of the domestic variables are not found to be consistent across countries, so that these relationships cannot be modelled in one specific way. To model each metal domestically, we use various time series techniques as dictated by the combined characteristics of the domestic variables.

The findings of this analysis reveal relationships that are not consistent across countries or precious metals. No consistent set of variables is found to exist that can explain either the short or the long run determinants of domestic precious metals prices, and there is no clear divide between developed or emerging markets. Any model of the determinants of a precious metal's domestic price requires individual handling by the practitioners or academics undertaking it, rather than assuming a single set of determinants as is frequently done.

1. Introduction

This study aims to examine the long run relationships between major macroeconomic factors and precious metals prices in their domestic context across developed and emerging economies from 1979 to 2020. To evaluate the long-run equilibrium, we assess the long-run and short-run relationship between prices of the main four precious metals (Gold, Silver, Platinum, and Palladium) and Consumer Price Index (CPI), Industrial Production (IP), Share Price (SP), Long-term Interest Rate (LIR), Short-term Interest Rate (SIR) and Unemployment Rate (UR).

The choice of this set of macroeconomic variables is motivated by what has been found in previous studies on precious metals (O'Connor, Lucey, Batten, & Baur, 2015; Vigne, Lucey, Connor, & Yarovaya, 2017). However, this will be the first paper to see if a consistent set of long and short run macroeconomic drivers can be used to explain the domestic price movements of these four precious metals.

We adopt various time series techniques that are most appropriate to the data's characteristics. We use the Autoregressive Distributed Lag (ARDL) and Johansen and Juselius (JJ) cointegration techniques to look for the existence of a long-run relationship between four precious metal prices and the six key macroeconomic factors. Monthly closing prices of four precious metals and the CPI, IP, SP, LIR, SIR, and UR were used from January 1979 to March 2020 prior to the Covid starting to have a major impact on macroeconomic variables.

The four precious metals (Gold, Silver, Platinum, and Palladium) and industrial metals (Aluminum, Copper, Lead, Nickel, Tin, and Zinc) are often viewed as two separate assets because of their different exposures to macroeconomic factors and different hedging properties (Gorton & Rouwenhorst, 2006; Roache & Rossi, 2010, Lucey, Aggarwal, and O'Connor (2016)). As a result, precious and industrial metals may be expected to demonstrate distinctive features.

However, the two metal groups share several characteristics that prevent them from being considered entirely distinct from one another. Precious metals are used in various products, such as electronics and communication equipment, spacecraft and jet aircraft engines, mobile phones, and catalytic converters. Gold, silver, platinum group metals, and palladium are most commonly recovered because they are found in electronics, X-ray films, photographic emulsions, industrial applications (catalysts, batteries, glass/mirrors), and jewelry (Canda, Heput, & Ardelean, 2016). But they differ from base metals in having a significant amount of long run investment demand, particularly gold.

Over the last few years, a substantial amount of research has been

* Corresponding author.
E-mail addresses: Hafiz.rana@bcu.ac.uk (H.M.U. Rana), fergal.oconnor@ucc.ie (F. O'Connor).

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published on the relationship between gold and inflation; however, the findings and conclusions are inconsistent across countries and time periods (O'Connor et al., 2015). In comparison to the large amount of research on the relationship between gold and inflation, research on the inflation hedging potential of white precious metals (Silver, Platinum and Palladium) is rare (Vigne et al., 2017).

This study is motivated by studies such as those mentioned above and Sharma (2016) who look at a wider range of countries and finds that while relationships between key macroeconomic variables exist with precious metals in the UK and USA – the same relationships don't hold in other countries. We aim to show which countries domestic prices are being driven by domestic variables over the long and the short run allowing for the idiosyncrasies of the data such as varying orders of integration.

We aim to fill a gap in the literature by improving our understanding of which macroeconomic factors have the most significant impact on the pricing of precious metals across a range of developed and emerging economies. Most previous studies tend to concentrate on a single economy, mainly developed economies such as the UK and the USA where data over long periods are available. They also do not look at whether a system exists between a number of macroeconomic variables and precious metals, instead focusing on the long run relationship between precious metals and one variable at a time, such as inflation or interest rates.

Investors cannot ignore the macroeconomy when constructing a portfolio or building a risk management strategy, and it has a significant impact on the behavior of commodity investors (Delatte & Lopez, 2013). Hence, it is vital that we fully comprehend the influences of macroeconomic factors such as inflation rate, interest rate, industrial production, share price movements, and unemployment rate on four precious metals volatility and provide advice to investors and policymakers accordingly.

Our results make two further contributions to literature. We show that due to the differing statistical characteristics of the macroeconomic variables across countries (e.g. unit roots or lack thereof) and the inconsistent relationships that exit between the variables (e.g. cointegration) there is no one way to model these relationships internationally. Additionally, relationships which as widely accepted in the literature, such as gold and CPI have a long run equilibrium relationship, does not hold in many of countries examined.

The remainder of the study is structured as follows; Section 2 discusses the literature on this topic. Section 3 describes the methodology, Section 4 explained the empirical results and we provide our conclusions in Section 5.

2. Literature review

Below, we discuss what we know to date about the impact of macroeconomic factors on precious metals prices. For full literature surveys of all four precious metals see O'Connor et al. (2015) for gold and Vigne et al. (2017) for the 4 white precious metals.

2.1. Inflation

Precious metals have been considered an effective inflation hedge for fiat currencies, owing to their naturally limited availability. Since the 1970's, the relation between gold prices and inflation has been extensively examined. The long history of gold as a currency during centuries, at least from 1500 BCE has motivated research in this sector (Hall, Hondroyiannis, Swamy, & Tavlas, 2011). Why this is the case is disputed with some arguing that gold miners imposed the increased costs due to inflation on investors, while O'Connor, Lucey, and Baur (2016) see the causality running in the opposite direction.

Bruno and Chincarini (2010) demonstrated that including gold in a portfolio allows investors to beat inflation and traditional assets in an inflationary scenario. Blose (2010) used CPI and forecasted change in CPI to analyze the influence of expected inflation on US gold prices and determined that gold prices do not vary owing to changes in inflation expectations.

To examine other precious metals, Bampinas and Panagiotidis (2015) investigated gold and silver's long-term hedging ability against UK and US CPI alternatives over a 200-year period. They reported that gold is an inflation hedge in the long run for both developed economies. Hoang (2011) confirmed Bampinas and Panagiotidis' findings. Sharma (2016) used data from 54 nations to see if the CPI predicts gold price returns and concluded that it does only in the UK and the US, raising questions about the generalizability of these relationships across a wider variety of countries.

Taylor (1998) used data from 1914 to 1996 to assess the inflation-hedging ability of white precious metals. The silver findings demonstrated a long-running hedge and a short-running hedge against the US CPI over many sub-periods. The findings using Johansen cointegration between platinum and palladium revealed that the two white precious metals could be used as a long-term inflation hedge. Batten, Lucey, McGroarty, Peat, & Urquhart, 2018 argue that white precious metals could provide an alternate and probably more efficient inflation shield as they change from output commodities to actively traded securities due to financialization.

2.2. Interest rate and precious metals

Wicksell (1907) first discussed the correlation between gold and the interest rates. The real interest rate is one of the most significant macroeconomic variables influencing investment holdings. Alternative investments like precious metals become more appealing as the real interest rates fall, and vice versa, as the opportunity cost of holding these non-interest-bearing assets would also fall.

Wang and Chueh (2013) reported that the nominal interest rates have a negative impact on gold prices. In addition, the interest rate can also be affected by gold and oil prices. The impact of shocks in the changing interest rate was examined by Cai, Cheung, and Wong (2001) and demonstrated that these surprises affect gold prices. However, Silva (2014) reported no association between gold prices and interest rates using 10 years of annual data, but there are still questions about the existence of unit root issues in their study and the short-term period examined coupled with the low frequency of the data.

Hammoudeh and Yuan (2008) employed GARCH-based models to examine the conditional volatility and instability of interest rates in the US economy and its effect on the prices of three important metals - silver, gold, and copper. According to Baur (2011), the relationship between gold and long-term interest rates differs from that of short-term interest rates for the USD again. Using monthly data spanning a 30-year period, he demonstrated that lower short-term interest rates have a positive effect on gold prices whereas higher long-term interest rates have a negative impact. These results are consistent with the findings of Abken et al. (1980) who reported a negative relationship between gold and short-term interest rates, and Fortune (1987) who found a negative relationship between gold and long-term interest rates. This apparent contradiction tends to suggest that short-term interest rates pose an opportunity cost to an investor, while long-term interest rates reflect inflation expectations, where higher anticipated inflation stimulates gold investment and pushes prices up. This finding indicates that any short-run gold price modelling should use short-term interest rates, as long-term rates are related to inflation, which is already used in long-run gold models.

Erb and Harvey (2013) observed a long-term inverse relationship between the real price of gold and the real interest rate for both UK and USA. They found a negative correlation of 0.82 over a 15-year period in the United States, and about 0.31 over a 30-year period in the United Kingdom. They were careful to emphasize the dangers of "correlation as causation" but they believe the association is convincing. Similarly, Scrimgeour (2015) argued that metal prices are more responsive against interest rates than agriculture commodities. Koutsoyiannis (1983) also reported that the nominal US interest rate has a relationship with precious metals in developing economies.

2.3. Industrial production

We consider industrial production to be an independent variable since precious metals are utilized in manufacturing processes – and this is a relationship with little research available to date. The abundant industrial usage of precious metals resulted in substitution among close metal cousins such as platinum and palladium, causing their prices to catch up with one another (Sari, Hammoudeh, & Soytas, 2010). The market for gold prevails in terms of monetary assets (36% investment holdings and 12% official holdings in 2012) and commodities (43% jewelry consumption). However, the demand of silver, platinum and palladium is higher as compared to gold mainly because of their industrial use, which accounts more than 50% of the total demand (Lucey & Li, 2015).

Platinum is an excellent catalyst that is used in many current industrial applications, most notably automotive catalytic converters, and future vehicle fuel cells are expected to rely on it. The automotive industry consumed roughly 40% of all extracted platinum during 2005 and 2010 (Alonso, Field, & Kirchain, 2012). Palladium and platinum are the most widely used precious metals in the industry. Moreover, declining demand for silver, also known as "gold of the poor," boosts interest in palladium in financial markets. Palladium is a less costly metal than gold and platinum because it has proven itself a popular alternative in financial markets over time and can be used as a vital hedging tool in financial markets in the near future (Richter, 2013).

Jain and Ghosh (2013) found that investors frequently purchase precious metals as a hedge against the risk of price co-movement caused by precious metals' common industrial use. Wang, Lee, and Thi (2011) also claimed that the shift in investment demand triggered by the anticipation of domestic currency depreciation is the primary reason why gold acts as a shield or safe haven against yen depreciation.

2.4. Share prices

The relationship between financial markets and gold has been extensively examined in the literature. However, few studies exist on white precious metals (silver, platinum, and palladium). Hillier, Draper, and Faff (2006) investigated the significance of three precious metals (gold, silver, and platinum) in the USA stock market. They suggested that these three precious metals have low correlations with US equity markets and can be used for portfolio diversification. Jain and Ghosh (2013) also found that platinum is a good hedging tool. Gold can be considered an enticing investment option during low investor confidence (Apergis, Cooray, Khraief, & Apergis, 2019).

To determine whether gold and other precious metals should be used as hedging tools or safe havens, Hood and Malik (2013) used the US stock market data, spanned the period from November 1995 to November 2010. The study's findings indicate that gold, unlike other precious metals, is a hedging investment in US stock markets and a weak but safe port. Simultaneously, Hood and Malik (2013) asserted that silver and platinum are ineffective hedging tools for the US stock market.

Baur and Lucey (2010) highlighted the significance of gold and suggested that it is a precious metal that investors choose as a short-term safe haven and is an effective hedging tool for the stock market in the United States, England, and Germany's financial markets. Arouri, Lahiani, and Nguyen (2015) investigated the return volatility distributions of global gold prices and the Chinese stock market between March 22, 2004, and March 31, 2011. The findings indicate significant return and volatility cross-effects between gold prices and Chinese stock market prices. As a result, gold returns should be factored into potential stock returns estimates, and gold is a significant hedging and safe-haven tool in this market. He, O'Connor, and Thijssen (2018) examine the same question using a Markov switching approach and find that rather than gold having a specific safe-haven phases, it is always acting as a hedge.

On the other hand, Low, Yao, and Faff (2016) analyzed whether investors preferred to include precious metals such as gold, silver, platinum, and palladium in their portfolios as jewelry or index investments for Australia, Germany, China, the United States, England, Brazil, and France from 2003 to 2013. The results revealed that these precious metals' investments were preferred more than the indices for which these precious metals were the underlying assets. Bailey and Bhaopichitr (2004) also examined the significance of silver in uncertain stock market environments, determining whether this precious metal can predict the expected risk premium in the stock market. Their findings indicated that silver has a significant impact on the stock market when forecasting changes in trade, economic growth, and inflation.

Many researchers (Raza, Shahzad, Tiwari, & Shahbaz, 2016) have reported in their research that co-movement between stocks and precious metals depends on inflation – highlighting the need to assess these variables as part of a system rather than individually. Sensoy (2013) find that investors choose precious metals such as gold, silver, platinum, and palladium in their portfolios for diversification and address uncertainty in the financial markets. In other words, for investors with alternative investment tools, such as stocks, bonds, futures, and foreign currency, the option of using precious metals is always desirable because of the diversification benefits. Following the 2008 financial crisis, commodity markets (gold, silver, platinum, and palladium) drew investor interest as alternative resources, similar to Islamic share markets (Jain & Ghosh, 2013).

The role of gold as a safe-haven asset has been widely studied in the literature. However, Lucey and Li (2015) investigated the safe heaven properties of four precious metals - gold, silver, platinum, and palladium in a time-varying manner and reported that white precious metals (silver, platinum, and palladium) sometimes act as safe havens, whereas gold does not work in the USA during the sample period they examined.

2.5. Unemployment rate

Thaver and Lopez (2016) analyzed the relationship between gold prices and the US unemployment rate over three different time periods between 1978 and 2016. The findings showed a long-run relationship between the price of gold and unemployment in both sub periods analyzed 1990–2016 and 2008–2016. However, no long-run cointegrated relationship between gold and unemployment was observed for the 1978–2016 period. Moreover, the authors suggested that the direct relationship between precious metals prices and unemployment has not been studied in the literature, so further research in this field may lead to a better understanding of this macroeconomic variable's effect on precious metals' price.

Literature suggests that the impact of the unemployment rate on metal markets has primarily been examined in the developed economies, particularly in the U.S.. Elder, Miao, & Ramchander, 2012 find that there is a substantial impact of U.S. macroeconomic news announcements on the precious metals, with announcements about the unemployment rate containing enough information to cause the metal market. Cai et al. (2001) analyzed 23 different U.S. macroeconomic announcements to determine if intraday trends significantly affect the dynamics of precious metals' return volatility. The study found that employment reports significantly influenced the dynamics of precious metals' return volatility. Christie-David, Chaudhry, and Koch (2000) argued that using intraday data throughout 1992–1995 resulted in a significant impact of the macroeconomic *news* release on gold and silver futures prices. Moreover, the author suggested the release of the Unemployment Rate affects both gold and silver.

Smales and Yang (2015) reported that the unemployment rate and GDP's macroeconomic announcements significantly impact precious metals prices. Becker, Finnerty, and Kopecky (1996) found that there is also a broad impact of macroeconomic factors on the prices of various treasury bonds and unemployment and inflation data after the announcement of economic variations. Additionally, Apergis, Christou, and Payne (2014) found that a higher unemployment rate has a negative effect on the price of silver in the US. Recently, Caggiano, Castelnuovo, and Figueres (2017) examined the response of the US unemployment rate to an economic policy uncertainty shock over the business cycle and found that the response of unemployment is statistically and economically more significant during recessions.

3. Data

We employ six major macroeconomic variables to determine the effect of these domestic macroeconomic variables on domestic precious metals prices. The log monthly domestic prices of gold, silver, platinum, and palladium have been used to stabilize the variance of each series, as published by Thomson Reuters in domestic currency in terms. The variables and sources are summarized in Table 1.

We study the period from January 1979 to March 2020, with a maximum of 501 and minimum of 85 monthly time series observations due to the absence of data for some countries during the sample period. We use London prices for the four precious metals as this has been found to be the dominant market for price discovery in a number of studies (Lucey, Larkin, and O'Connor (2014), Corbet and O'Connor (2021), Lucey, Larkin, and O'Connor (2013)) the US and the UK markets have been found to be where price discovery is. Some variables missing as not available monthly.

The descriptive statistics of the data for each country are summarized in the appendix in Tables 10, 11, 12, 13 and 14. These tables demonstrate that the mean values of four precious metal prices and the major macroeconomic variables substantially vary across developed and emerging economies.

4. Results

The strategy used to test whether they macroeconomic relationships exist across the countries examined is shown in Fig. 1 below and explained here. If all data for a metal and set of macroeconomic variables in a country were found to be I(0) we could simply apply OLS or a Vector Autoregressive Model (VAR), such as Eq. (1) but this is not found for these variables.

$$Y = \alpha + \beta 1Y + \beta 2Z + \beta 3A \tag{1}$$

As many of the variables used here are I(1) then we cannot use OLS directly because the regression in levels would be spurious. We apply Johansen and Juselius (1990) to test for cointegrating long run relationships as a first step when all variable are found to be non-stationary for a country and metal set.

If cointegration exists in a single equation, we can directly apply OLS to the levels data, and we would use a Vector Error Correction Model (VECM) to model the short run relationship. In contrast, if cointegration does not exist, we cannot use OLS on the levels data; instead, we must use OLS/VAR on the first differenced (stationary) data.

Lastly, if variables are of a mixed order of integration, that is some variables are stationary in levels while others are stationary first differences, an Autoregressive Distributed Lag (ARDL) approach is used. Although the ARDL cointegration technique does not require pre-testing for unit roots, unit root tests are be performed to determine their order of integration in order to prevent the ARDL model from collapsing in the presence of an integrated stochastic pattern of I(2) variables (Nkoro, Uko, et al., 2016).

Table 1
Variable description.

Name variables	Source	Symbol
Gold (Price)	Thomson Reuters	Gold
Silver (Price)	Thomson Reuters	Silver
Platinum (Price)	Thomson Reuters	Platinum
Palladium (Price)	Thomson Reuters	Palladium
Inflation	IMF	CPI
Industrial Production	OECD	IP
Short-term Interest Rate	OECD	SIR
Long-term Interest Rate	OECD	LIR
Share Price	OECD	SP
Unemployment Rate	The Global Economy	UR

4.1. Stationarity tests

To test unit root properties of variables, unit root tests are employed to test the stationarity and non- stationarity. A summary of the results of the ADF and PP tests are displayed in Table 2, indicating which cointegration test will be undertaken based on this pre-testing. Full results are available from the authors on request.

4.2. Johansen cointegration test results

The Johansen trace test is employed to determine whether countries where all variables were found to be I(1) are cointegrated. The Trace and Max Eigenvalue (TME) statistics are used to analyze the results of Johansen Cointegration. The model lag length selection was determined by Akaike (AIC) Information Criterion.

Full results for the Johansen tests are reported in Tables 15 to 18 of the Appendix and are summarized below in Table 3 below. We find cointegrating relationships between the macroeconomic variables and gold in Australia Japan and China, but no long run equilibrium relationship is found to exist between the macroeconomic variables considered here and gold in India.

Silver is found to have a long run equilibrium relationship with the macroeconomy in both China and India. For China the Max and Trace tests disagree but as the trace tests indicates a cointegrating relationship we take that as the correct result as per Lüutkepohl, Saikkonen, and Trenkler (2001). For platinum cointegration is found to exist for the USA, UK and China, and for palladium in Australia and USA.

The countries not examined in Table 3 will be assessed under an ARDL approach below due to mixed orders of integration.

4.2.1. Long-run relationship

After normalization on the precious metals prices, the cointegrating vector on gold, silver, platinum, and palladium normalized cointegrating coefficients is estimated and reported in Table 4, based on the results above.

Long run equilibrium Australian gold prices had a long-term positive correlation with the Consumer Price Index and Long-term Interest Rates, suggesting that the gold market hedged against inflation. The long-term relationship between gold and share prices was negative, suggesting that the Australian stock market moves opposite to gold as investors move their money from risky to safe assets at different times in the cycle. Short term interest rates and Unemployment have an insignificant effect on long-run gold prices in Australia.

Japanese gold prices have similar relationship with CPI, Share prices and long run interest rates - with short run interest rates also having a significant. Here, where monthly industrial production data is available, higher industrial production is associated with a lower gold price, but lower unemployment with higher gold prices as consumers have more purchasing power during periods of low unemployment. As these both reflect the real economy and economic grow the difference in signs here will warrant further investigation.

Chinese gold prices have a positive relationship with CPI, IP, LIR, and UR, but only with CPI and UR is the relationship significant, implying that higher gold prices hedge against inflation and lower unemployment because consumers have more purchasing power during periods of low

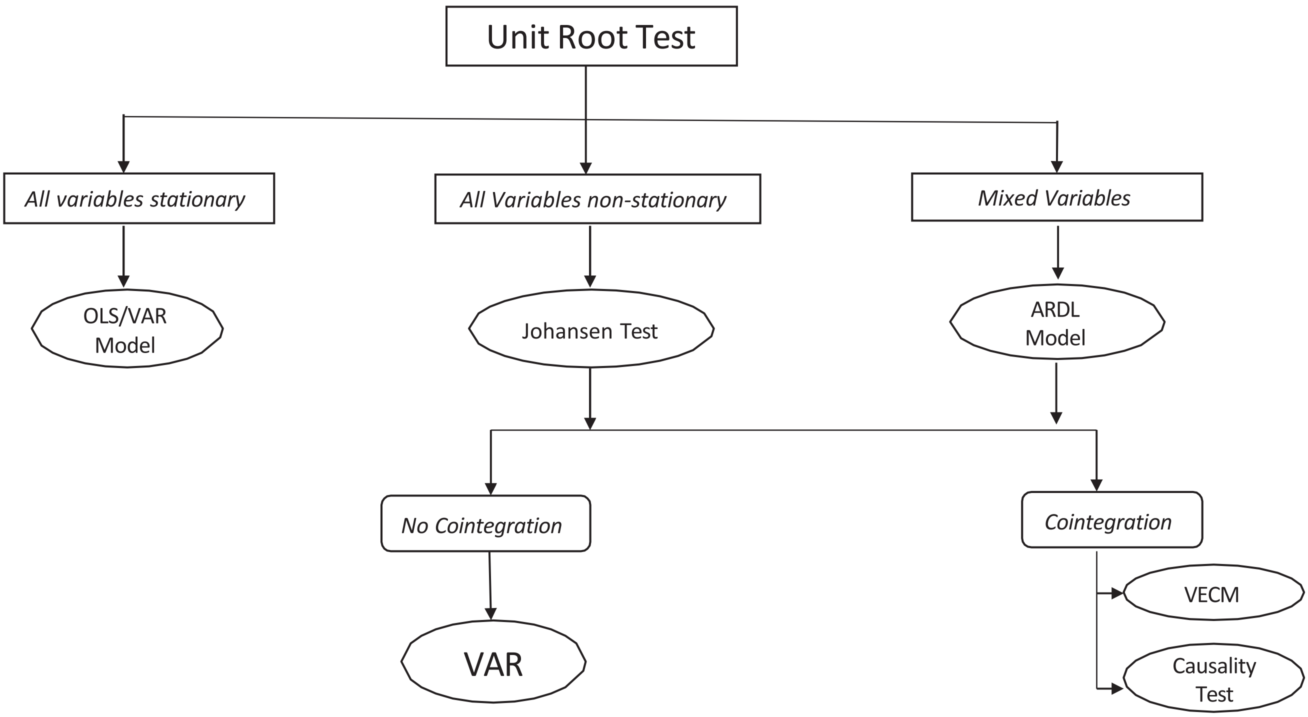

Fig. 1. Time series model selection.
*Source:*Shrestha and Bhatta (2018).

Table 2
Model selection summary.

Country	Gold		Silver		Platinum		Palladium	
Australia	All I(1)	Johansen	–	–	Not all I(1)	ARDL	Not all I(1)	ARDL
UK	Not all I(1)	ARDL	Not all I(1)	ARDL	All I(1)	Johansen	–	–
USA	Not all I(1)	ARDL	Not all I(1)	ARDL	All I(1)	Johansen	All I(1)	Johansen
Japan	All I(1)	Johansen	–	–	–	–	–	–
Switzerland	Not all I(1)	ARDL	Not all I(1)	ARDL	–	–	–	–
Mexico	Not all I(1)	ARDL	Not all I(1)	ARDL	–	–	–	–
China	All I(1)	Johansen	All I(1)	Johansen	All I(1)	Johansen	–	–
India	Not all I(1)	ARDL	Not all I(1)	ARDL	–	–	–	–

Table 3
Johansen test results.

Metal	Australia	Japan	USA	UK	China	India
Gold	Cointegration - > VECM	Cointegration - > VECM	–	–	Cointegration - > VECM	No Cointegration - > VAR
Silver	–	–	–	–	Cointegration - > VECM	Cointegration - > VECM
Platinum	–	–	Cointegration - > VECM	Cointegration - > VECM	Cointegration - > VECM	–
Palladium	Cointegration > VECM	–	Cointegration > VECM	–	–	–

unemployment.

Chinese silver also hedged inflation in the long-term positive and a significant negative relationship with interest rates indicating an opportunity cost to holding silver as a non-cash generating asset. Lower unemployment gives higher longer-term Chinese silver prices as consumers would have more purchasing power. Higher interest rates drive down Chinese silver prices, in what can be interpreted as an opportunity cost effect.

Indian silver prices show exactly the opposite relationship to long-run interest rates – rising together while no relationship is found with short run interest rates. A negative relationship with industrial production also exists – similarly to Japan for gold.

As platinum and palladium are more industrial metals (where gold and to a lesser extent silver are more investment metals) we might expect different relationships to exist. For CPI in the three countries examined platinum prices rise with inflation – as is the case for gold and silver – and CPI is the only driver in the long run for the USA and China. For the UK a negative relationship exists with industrial production. Industrial production is an insignificant driver in the long run for US and Chinese Platinum prices. In the UK platinum prices rise with equity markets in contrast to findings for gold and higher inserts rates mean higher equilibrium platinum prices in Great British Pounds. Lastly for

Table 4
Normalized cointegrating coefficients.

	CPI	IP	SP	SIR	LIR	UR
Gold						
Australia	−12.43**	–	1.60**	−0.01	−1.78**	−0.28
Japan	−5534.05**	1935.41**	366.77**	−30,940.70**	−15,268.80**	872.70**
China	−18.85**	−0.18	0.08	0.25	−0.11	−1.14**
Silver						
China	−17.34**	−0.50**	0.07	0.07	0.30	−1.27**
India	0.73	0.23**	0.78	0.37	−0.43**	–
Platinum						
USA	−17.31**	2.59	−1.17	−0.08	0.30	−1.10
China	−0.29**	−0.70	0.10	−1.83		−0.68
UK	−67.88**	148.43***	−4.89**	−9.60**	−3.14**	5.87**
Palladium						
USA	589.16**	222.96**	−253.92**	−31.26**	28.53**	–

Note: ***, **, * indicates significance at the 1, 5 and 10% level.

the UK higher unemployment means lower prices – showing its industrial side again.

Palladium prices in USA exhibited a negative long-term relationship with the CPI, while palladium prices showed a significant positive relationship with the short and long-term interest rates.

4.2.2. The short run relationship

Vector Error Correction Models (VECM) for the above countries and metals are shown below in Table 5, examining the dynamic relationships between macroeconomic variables and precious metals across developed and emerging markets using the same underlying macroeconomic factors as variables. The results of the VECM model are presented in Table 5.

For Australian gold prices the ECM term is negative (−0.02) and is highly significant at 5%, implying a long run equilibrium relationship exists but that the half-life of the error is around 34 months[1]. However, in Japan and China, while the ECM terms are negative (−0.01 and −0.43) it is insignificant implying that there is no long-run causality running from the macroeconomic variables to Australian gold prices. However, in both cases the short run variation in those prices cannot be explained using the same variables as were used in the long run analysis, as all variables and lags are insignificant.[2]

For silver in India a valid ECM exists with a half-life of only 3 months implying a swift return to equilibrium, but for the UK the ECM term is again insignificant. For Platinum the half life of a disequilibrium in the USA and China are just under a year and just over 2 months respectively. Palladium in the US again fails to provide a significant and negative ECM term, raising further questions about its long run equilibrium.

4.2.3. Wald test statistics – causality tests

We now assess whether causality exists between the above variables in Table 5. The Wald test is a method to determine whether explanatory variables in a model are significant. To examine the short-run causality between dependent and independent variables, we used the F statistics of the Wald test (Banumathy & Azhagaiah, 2015).

In this study, we investigated the impact of each independent variable over the dependent variable separately, whether the independent variable can cause a dependent variable in the short-run or not. The results of the Wald test for Gold Australia, Japan, Silver India, Platinum UK, USA and China, and Palladium USA are presented respectively in Table 6.

The findings of the Table 6 revealed that there is no short-run causality between the dependent variables (gold, silver, platinum, and palladium) and independent variables (CPI, IP, SIR, LIR, UR) in the emerging markets. However, the short -run relationship exist between the dependent and independent variables in the developed markets. For instance, the short-run relationship exists in the USA between IP & Platinum, SIR & Platinum, LIR & Platinum, CPI & Palladium, SP & Palladium, IP & Gold in Japan, and SP & Platinum in the United Kingdom.

4.3. Vector auto regression model (VAR) results

Table 7 presents results based on the vector autoregressions (VAR) for monthly log differenced gold prices for India and palladium prices in Australia. For these countries and domestic precious metals prices we found that all variables were I(1) but no cointegration existed based on the Johansen Cointegration tests. Therefore, no long run relationship exists between these macroeconomic variables and these domestic precious metals prices. Below we run a VAR in first difference to assess the short run relationships.

Both prices suffer from first order positive monthly autocorrelation. But other than that, these macroeconomic variables do not provide a good explanation of the short run price movements here with no other variable being significant. Only the first monthly lag is significant.

4.4. Autoregressive distributed lag (ARDL)results

This section addresses relationships where there was a mixture of orders of integration, and an Autoregressive Distributed Lag Approach (ARDL) technique or ARDL Bound Testing is used to capture the long-run relationship among the dependent and independent variables.

In Table 8, we use the ARDL bond testing to examine the long-run relationship among the variables. The results indicate that there is no long-run relationship exist between precious metals price and macroeconomic variables. Hence, we accept the null hypothesis at the 5% and 10% level that no.

long-run relationship exists between the domestic precious metals prices and the macroeconomic variables examined.

4.5. Short- run relationship - Wald test statistics

Table 9 demonstrates that outcomes vary by country in the short run. For gold, interest rates are shown to have an important role, with Long Run rates having a significant relationship with changes in gold prices in the UK, USA and Switzerland. Short Run interest rates have a significant and positive relationship with domestic gold price changes in the USA, Switzerland and Mexico – though sometimes the relationship is weaker. CPI only has explanatory power for gold price changes in the USA and Mexico. The Unemployment rate, share prices and Industrial production have no statistical significance in these short run equations for gold.

For silver share prices in the UK, Switzerland, and Mexico have explanatory power. In addition, the short -run relationship exist between

[1] Calculated as ln(2)/(|ECM term|)

[2] We also tested the short-run causality test using Wald test and found the qualitative results similar to Table 5.

Table 5
Vector error correction model results.

	Gold			Silver		Platinum		Palladium
	Australia	Japan	China	India	UK	USA	China	USA
ECM Term	−0.02**	−0.01	−0.43	−0.23**	0.00	−0.06***	−0.30***	0.00
Lag 1	0.03	−0.19	0.19	0.05	−0.01	−0.08	−0.18	−0.12
Lag 2	−0.03	−0.12	−0.07	0.13	0.04	0.14***	–	0.03
Lag 3	−0.02	–	−0.28	–	0.04	–	–	–
CPI Lag 1	0.06	0.06	−5.97	−0.64	−1.51***	−0.75	0.34	1.07
CPI Lag 2	1.21	−2.06	−3.54	0.23	−0.51	−1.72***	–	−4.53
CPI Lag 3	0.36	–	−3.87	–	−0.57	–	–	–
IP Lag 1	–	−0.20	0.21	0.26	0.06	0.94***	0.02	0.89
IP Lag 2	–	0.04	0.18	0.04	0.14	0.94***	–	−0.22
IP Lag 3	–	–	0.10	–	0.40	–	–	–
SP Lag 1	−0.01	0.02	−0.09	0.26	0.28	0.37***	0.06	0.36
SP Lag 2	−0.01	−0.03	0.08	−0.21	0.16	0.10	–	0.30
SP Lag 3	−0.02	–	−0.04	–	0.00	–	–	–
SIR Lag 1	0.00	2.07	0.45	0.20	−0.13	−0.07***	0.22	−0.05
SIR Lag 2	0.01	−3.81	−0.26	0.04	−0.07	−0.05	–	−0.02
SIR Lag 3	−0.08	–	−0.11	–	0.05	–	–	–
LIR Lag 1	0.03	−1.05	−0.16	0.24	−0.07	−0.10	–	−0.09
LIR Lag 2	−0.04	5.64	−0.18	−0.46	0.14***	0.16***	–	0.05
LIR Lag 3	0.05	–	0.00	–	−0.09	–	–	–
UR Lag 1	0.04	0.05	−0.06	–	−0.01	0.07	0.06	−0.13
UR Lag 2	0.09	−0.13	−0.35	–	0.19	0.12	–	−0.15
UR Lag 3	−0.11	–	−0.10	–	−0.31	–	–	–

Note: ***, **, * indicates significance at the 1, 5 and 10% level.

Table 6
Wald test statistics - F statistics.

Variable	Australia	USA	Japan	UK	India	China
CPI & Gold	1.87	–	1.51	–	–	–
IP & Gold	–	–	0.80	–	–	–
SP & Gold	0.09	–	0.09	–	–	–
SIR & Gold	1.35	–	0.02	–	–	–
LIR & Gold	0.44	–	0.83	–	–	–
UR & Gold	1.04	–	1.06	–	–	–
CPI & Silver	–	–	–	–	0.19	–
IP & Silver	–	–	–	–	0.14	–
SP & Silver	–	–	–	–	0.67	–
SIR & Silver	–	–	–	–	0.73	–
LIR & Silver	–	–	–	–	1.43	–
CPI & Platinum	–	2.12	–	2.19	–	0.55
IP & Platinum	–	3.32**	–	0.52	–	0.87
SP & Platinum	–	2.80	–	7.50***	–	0.35
SIR & Platinum	–	9.09**	–	2.67	–	–
LIR & Platinum	–	4.78**	–	0.69	–	–
SIR & Platinum	–	–	–	–	–	1.61
UR & Platinum	–	0.19	–	1.14		0.58
CPI & Palladium	–	4.12**	–	–	–	–
IP & Palladium	–	0.83	–	–	–	–
SP & Palladium	–	6.53***	–	–	–	–
SIR & Palladium	–	1.00	–	–	–	–
LIR & Palladium	–	0.78	–	–	–	–
UR & Palladium	–	0.93	–	–	–	–

Note: ***, **, * indicates significance at the 1, 5 and 10% level. Chi-square stats available on request.

Table 7
Vector auto regression model results, first differences.

	Gold	Palladium
Variables	India	Australia
Lag 1	0.65**	0.88**
Lag 2	0.03	0.10
CPI lag 1	0.12	1.18
CPI lag 2	−0.30	−2.42
IP lag 1	−0.01	–
IP lag 2	0.34	–
SP lag 1	0.01	0.00
SP lag 2	−0.01	0.03
SIR lag 1	−0.02	0.06
SIR lag 2	−0.14	−0.04
LIR lag 1	0.10	0.12
LIR lag 2	−0.00	−0.16
UR lag 1	–	−0.16
UR lag 2	–	0.22

silver and the unemployment rate in the USA and for consumer price index in Switzerland and Mexico. Short run interest rates influence US Dollar silver price changes.

For platinum Australia, the short-run relationship exists between platinum and: CPI, Shar Price changes and the Unemployment Rate but not SIR and LIR.

5. Conclusion

This study investigated the long-run and short-run relationship between domestic prices of the four main precious metals, and major macroeconomic variables such as the Consumer Price Index, Industrial Production, Share Price, Long-term Interest Rate, Short-term Interest Rate and Unemployment Rate. We used various cointegration techniques across a range of countries to assess whether long run relationships existed. Prices of precious metals fluctuate in response to changes in macroeconomic factors, which is a significant economic indicator. The changes in the price of precious metals are an essential indicator of the economy's health since these metals have historically served as a good hedge against inflation and are therefore highly valuable. Certain investors prefer interest payments above long-term appreciation on their precious metals' holdings.

The findings demonstrate some evidence of long run cointegrating relationships between monthly domestic precious metals prices and the Consumer Price Index, Industrial Production, Share Price, Long-term Interest, Short-term Interest Rate over the last forty years. Cointegrating relationships exist between domestic gold prices in Australia Japan and China (under a Johansen test) but not in the USA and the UK, under and ARDL Bounds methodology.

Emerging markets like India see no Johansen co-integration between gold prices and macroeconomic variables. However, silver, a metal with more industrial demand than gold, does have long run cointegrating relationships with the macroeconomic variables used in this study. Similarly in all countries for platinum and palladium where all variables are I(1), a long run cointegrating relationship is found to exist. However,

Table 8
Long-Run ARDL results - Bound test.

Variable	Significance	I(0) Bound	I(1) Bound	F-statistics	Outcome
Gold UK	10% 5%	2.12 2.45	3.23 3.61	0.38	No Long-Run Relationship
Gold USA	10% 5%	2.03 2.32	3.23 3.61	1.10	No Long-Run Relationship
Gold Switzerland	10% 5%	2.26 2.62	3.35 3.79	2.77	No Long-Run Relationship
Gold Mexico	10% 5%	2.12 2.45	3.23 3.61	2.50	No Long-Run Relationship
Silver UK	10% 5%	2.03 2.32	3.13 3.54	1.05	No Long-Run Relationship
Silver USA	10% 5%	2.12 2.45	3.23 3.61	2.10	No Long-Run Relationship
Silver Switzerland	10% 5%	2.26 2.62	3.35 3.79	2.98	No Long-Run Relationship
Silver Mexico	10% 5%	2.26 2.62	3.35 3.79	2.70	No Long-Run Relationship
Silver China	10% 5%	2.26 2.62	3.35 3.79	2.50	No Long-Run Relationship
Platinum Australia	10% 5%	2.26 2.62	3.35 3.79	2.75	No Long-Run Relationship
Palladium Australia	10% 5%	2.26 2.62	3.35 3.79	2.12	No Long-Run Relationship

Note: ***, **, * indicates significance at the 1, 5 and 10% level.

ARDL tests on those with mixed orders of integration find no long run relationships to hold.

The signs on the long-run coefficients estimated for these relationships are not the same between countries – even when the relationships are found to be significant. For example – silver in China has a positive relationship with short run interest rates, while in India the relationship is negative. Additionally, statistically significant relationships between a domestic precious metals price and a macroeconomic in one country for a metal is not replicated across the sample.

When VECM models are developed based on cointegrating relationship very few macroeconomic variables used here have explanatory power at this monthly frequency for the short run. In some cases, such as silver in India, the half-life of a disequilibrium was found to be very short while for other such as Palladium in the USA no valid ECM is found to exist. An exception to this rule is Platinum in the USA where the VECM finds a negative relationship to CPI and Short Run interest rates, a positive relationship to share prices, long run interest rates and Industrial production.

For the country and precious metals relationships where either no Johansen cointegration was found or where there were mixed orders of integration and ARDL Bounds tests were used no long run relationships were found with these sets of variables. Some short run relationships were found to be present in these cases but again no unifying set of variables for any metal were found to be consistently important.

This paper shows that using the domestic macroeconomic factors most commonly associated with precious metal prices in the literature across a wider sample of countries does not lead consistent system of variables to explain the price movements of these metals in the long or the short run. Further investigations into each individual domestic precious metal's prices and its drivers are needed to create heterogenous model to aid hedger and investors in understanding these commodities.

Data availability

The authors do not have permission to share data.

Appendix

This section contains all of the descriptive statistics and unit root test tables.

Table 9
Short- Run ARDL results WALD Test - F-statistics.

Variables	UK	USA	Australia	Switzerland	Mexico	China
Gold	2652***	15048***	–	4192***	50.04***	–
CPI	1.56	4.50***	–	0.02	5.20**	–
IP	1.49	3.24	–	–	1.48	–
SP	1.39	1.86	–	2.69	–	–
SIR	1.00	3.71**	–	2.09*	2.68*	–
LIR	6.15**	5.67**	–	3.88**	1.01	–
UR	2.58	0.16	–	2.48	–	–
Silver	1777***	1759***	–	2589***	1210***	328***
CPI	2.68	1.89	–	2.29**	3.03**	2.22
IP	0.002	0.25	–	–	0.60	0.23
SP	3.55**	2.70	–	3.04**	4.63**	2.62
SIR	2.04	4.41**	–	2.51	1.21	1.37
LIR	2.41	2.13	–	0.01	–	–
UR	0.24	4.29**		1.39	2.39	0.10
Platinum	–	–	1259***	–	–	–
CPI	–	–	7.39**	–	–	–
IP	–	–	–	–	–	–
SP	–	–	3.04**	–	–	–
SIR	–	–	1.49	–	–	–
LIR	–	–	2.36	–	–	–
UR	–	–	8.57**	–	–	–

Note: ***, **, * indicates significance at the 1, 5 and 10% level. Chi-square stats available on request.

Table 10
Descriptive statistics - Gold.

Country	Variable	Mean	Median	SD	Max	Min	Skewness	Kurtosis
	Gold	5.89	5.54	0.65	7.13	5.06	0.59	1.66
	CPI	4.43	4.44	0.24	4.79	3.88	−0.48	2.42
	IP	4.59	4.61	0.05	4.67	4.40	−1.43	5.13
UK	SP	4.19	4.37	0.45	4.76	3.06	−0.79	2.39
	SIR	1.16	1.66	1.17	2.73	−1.27	−0.60	1.83
	LIR	1.51	1.59	0.69	2.54	−0.55	−0.73	2.79
	UR	1.87	1.87	0.29	2.42	1.31	0.05	1.99
	Gold	6.56	6.31	0.56	7.92	5.28	0.63	2.17
	CPI	0.04	0.03	0.03	0.12	0.00	0.88	2.55
	IP	–	–	–	–	–	–	–
Australia	SP	3.78	3.98	0.78	4.85	1.93	−0.65	2.37
	SIR	1.76	1.73	0.80	3.06	−2.30	−1.36	7.58
	LIR	1.87	1.82	0.63	2.80	−0.15	−0.76	3.44
	UR	1.89	1.83	0.25	2.42	1.38	0.35	2.24
	Gold	6.58	6.51	0.40	7.42	5.94	0.30	1.72
	CPI	4.43	4.50	0.19	4.62	3.92	−1.00	2.72
	IP	–	–	–	–	–	–	–
Switzerland	SP	3.67	4.08	0.84	4.72	2.09	−0.45	1.68
	SIR	0.03	0.02	0.03	0.10	−0.01	0.76	2.75
	LIR	0.03	0.02	0.03	0.10	−0.01	0.76	2.75
	UR	0.02	0.03	0.01	0.06	0.00	−0.06	1.87
	Gold	11.42	11.60	0.46	11.93	10.50	−0.72	2.01
	CPI	4.62	4.61	0.02	4.66	4.60	0.74	2.23
	IP	4.64	4.63	0.07	4.79	4.36	−0.45	4.84
Japan	SP	4.33	4.34	0.28	4.79	3.85	−0.10	1.72
	SIR	0.00	0.00	0.00	0.01	0.00	1.19	3.34
	LIR	0.01	0.01	0.01	0.02	0.00	−0.37	1.93
	UR	1.39	1.41	0.22	1.70	0.83	−0.67	2.70

Table 11
Descriptive statistics - Gold continued.

Country	Variable	Mean	Median	SD	Min	Max	Skewness	Kurtosis
	Gold	6.31	6.02	0.60	7.58	5.45	0.64	1.87
	CPI	4.30	4.35	0.34	4.78	3.44	−0.50	2.23
	IP	4.35	4.50	0.28	4.69	3.80	−0.53	1.74
USA	SP	3.60	3.96	0.93	4.87	1.70	−0.53	1.97
	SIR	0.99	1.59	1.36	2.93	−2.21	−0.94	2.72
	LIR	1.63	1.67	0.82	2.79	−1.56	−1.06	4.04
	UR	1.79	1.76	0.27	2.69	1.25	0.26	2.51
	Gold	9.06	9.04	0.13	9.36	8.82	0.48	2.50
	CPI	4.72	4.73	0.06	4.81	4.59	−0.53	2.42
	IP	–	–	–	–	–	–	–
China	SP	4.30	4.33	0.19	4.86	4.00	0.21	2.58
	SIR	−0.14	−0.28	0.21	−0.33	0.33	0.84	2.32
	LIR	1.24	1.25	0.13	1.00	1.50	−0.07	2.33
	UR	1.21	1.19	0.12	1.57	0.99	1.00	4.40
	Gold	11.31	11.32	0.07	11.45	11.16	−0.24	2.19
	CPI	4.98	5.00	0.11	5.15	4.72	−0.54	2.30
	IP	4.62	4.61	0.08	4.78	4.50	0.25	1.89
India	SP	4.53	4.58	0.23	4.94	4.09	−0.22	1.95
	SIR	2.00	2.01	0.15	2.43	1.71	0.15	2.25
	LIR	2.05	2.06	0.08	2.20	1.88	−0.33	2.51
	UR	–	–	–	–	–	–	–
	Gold	9.28	9.38	0.87	10.75	7.95	−0.16	1.43
	CPI	4.49	4.52	0.32	4.98	3.69	−0.50	2.51
	IP	4.49	4.48	0.11	4.69	4.22	0.11	2.33
Mexico	SP	3.76	4.20	0.89	4.76	2.04	−0.51	1.64
	SIR	2.07	2.04	0.58	3.70	1.19	0.70	2.89
	LIR	–	–	–	–	–	–	–
	UR	1.33	1.31	0.23	1.79	0.74	−0.08	2.39

Table 12
Descriptive statistics - Silver.

Country	Variable	Mean	Median	SD	Max	Min	Skewness	Kurtosis
	Silver	1.69	1.32	0.69	3.38	0.62	0.57	1.91
	CPI	4.43	4.44	0.24	4.79	3.88	−0.48	2.42
	IP	4.59	4.61	0.05	4.67	4.40	−1.43	5.13
UK	SP	4.19	4.37	0.45	4.76	3.06	−0.79	2.39
	SIR	1.16	1.66	1.17	2.73	−1.27	−0.60	1.83
	LIR	1.51	1.59	0.69	2.54	−0.55	−0.73	2.79
	UR	1.87	1.87	0.29	2.42	1.31	0.05	1.99
	Silver	5.91	5.82	0.50	7.04	5.02	0.25	1.92
	CPI	4.47	4.53	0.14	4.62	4.13	−1.04	2.68
	IP	–	–	–	–	–	–	–
Switzerland	SP	3.83	4.14	0.73	4.72	2.28	−0.59	1.85
	SIR	0.02	0.02	0.03	0.09	−0.01	0.85	2.98
	LIR	0.03	0.03	0.02	0.07	−0.01	−0.18	2.32
	UR	0.03	0.03	0.01	0.06	0.00	−0.14	2.07
	Silver	2.16	1.90	0.64	3.78	1.28	0.56	2.05
	CPI	4.37	4.40	0.28	4.78	3.80	−0.36	1.95
	IP	4.40	4.53	0.24	4.69	3.83	−0.69	1.97
USA	SP	3.77	4.05	0.78	4.87	2.11	−0.56	2.05
	SIR	0.85	1.39	1.30	2.45	−2.21	−0.95	2.63
	LIR	1.55	1.62	0.74	2.54	−1.29	−0.92	3.38
	UR	1.77	1.72	0.27	2.69	1.25	0.36	2.67
	Silver	8.41	8.31	0.28	9.27	8.05	0.97	2.83
	CPI	4.72	4.73	0.06	4.81	4.59	−0.53	2.42
China	IP	2.16	2.12	0.37	3.03	1.67	0.67	2.23
	SP	4.30	4.33	0.19	4.86	4.00	0.21	2.58
	SIR	−0.1	−0.2	0.21	−0.3	0.33	0.84	2.32
	LIR	1.24	1.25	0.13	1.00	1.50	−0.07	2.33
	UR	1.21	1.19	0.12	1.57	0.99	1.00	4.40
	Silver	10.6	10.5	0.13	11.0	10.40	1.11	0.23
	CPI	4.98	5.00	0.11	5.15	4.72	−0.54	2.30
	IP	4.62	4.61	0.08	4.78	4.50	0.25	1.89
India	SP	4.53	4.58	0.23	4.94	4.09	−0.22	1.95
	SIR	2.00	2.01	0.15	2.43	1.71	0.15	2.25
	LIR	2.05	2.06	0.08	2.20	1.88	−0.33	2.51
	UR	–	–	–	–	–	–	–
	Silver	5.08	5.30	0.79	6.50	3.70	−0.25	1.59
	CPI	4.49	4.52	0.32	4.98	3.69	−0.50	2.51
	IP	4.49	4.48	0.11	4.69	4.22	0.11	2.33
Mexico	SP	3.76	4.20	0.89	4.76	2.04	−0.51	1.64
	SIR	2.07	2.04	0.58	3.70	1.19	0.70	2.89
	LIR	–	–	–	–	–	–	–
	UR	1.33	1.31	0.23	1.79	0.74	−0.08	2.39

Table 13
Descriptive statistics - Platinum.

Country	Variable	Mean	Median	SD	Max	Min	Skewness	Kurtosis
UK	Platinum	6.56	6.43	0.53	7.68	5.82	0.27	1.71
	CPI	4.43	4.44	0.24	4.79	3.88	−0.48	2.42
	IP	4.59	4.61	0.05	4.67	4.40	−1.43	5.13
	SP	4.19	4.37	0.45	4.76	3.06	−0.79	2.39
	SIR	1.16	1.66	1.17	2.73	−1.27	−0.60	1.83
	LIR	1.51	1.59	0.69	2.54	−0.55	−0.73	2.79
	UR	1.87	1.87	0.29	2.42	1.31	0.05	1.99
Australia SP	Platinum	6.92	7.06	0.44	7.74	6.09	−0.51	1.84
	CPI	0.02	0.02	0.01	0.06	0.00	0.72	3.87
	IP	–	–	–	–	–	–	–
		4.19	4.29	0.43	4.85	3.18	−0.49	2.09
	SIR	1.43	1.59	0.62	2.48	−2.30	−2.14	11.40
	LIR	5.49	5.52	2.33	11.53	0.86	0.33	2.83
	UR	1.85	1.77	0.26	2.42	1.38	0.64	2.43
USA	Platinum	6.71	6.79	0.52	7.64	5.83	−0.18	1.79
	CPI	4.52	4.56	0.17	4.78	4.21	−0.23	1.73
	IP	4.54	4.58	0.11	4.69	4.20	−1.41	4.30
	SP	4.21	4.22	0.41	4.87	3.20	−0.66	3.00
	SIR	0.38	0.72	1.32	1.91	−2.21	−0.57	1.90
	LIR	1.21	1.49	0.72	2.19	−1.56	−1.19	4.42
	UR	1.71	1.69	0.28	2.69	1.25	0.75	3.01
	Platinum	5.61	5.64	0.23	5.99	5.21	−0.01	1.64
	CPI	4.72	4.73	0.06	4.81	4.59	−0.54	2.43
China	IP	2.16	2.13	0.37	3.03	1.67	0.68	2.23

(continued on next page)

Table 13 (*continued*)

Country	Variable	Mean	Median	SD	Max	Min	Skewness	Kurtosis
	SP	4.30	4.34	0.19	4.86	4.00	0.21	2.56
	SIR	−0.1	−0.2	0.21	−0.3	0.33	0.84	2.32
	LIR	1.24	1.25	0.13	1.00	1.50	−0.07	2.33
	UR	1.21	1.19	0.12	1.57	0.99	1.04	4.46

Table 14
Descriptive statistics - Palladium.

Country	Variable	Mean	Median	SD	Max	Min	Skewness	Kurtosis
	Palladium	5.76	5.77	0.84	7.82	4.38	0.25	2.05
	CPI	4.43	4.44	0.24	4.78	3.93	−0.33	1.96
	IP	4.46	4.55	0.20	4.69	4.02	−0.84	2.13
USA	SP	3.95	4.12	0.64	4.87	2.59	−0.58	2.10
	SIR	0.67	1.15	1.32	2.31	−2.21	−0.83	2.33
	LIR	1.43	1.57	0.77	2.54	−1.56	−1.56	4.17
	UR	1.74	1.70	0.26	2.69	1.25	0.56	3.02
	Palladium	6.34	6.36	0.70	8.20	4.99	0.26	2.64
	CPI	0.02	0.02	0.01	0.06	0.00	0.58	3.95
	IP	–	–	–	–	–	–	–
Australia	SP	4.31	4.39	0.34	4.85	3.50	−0.47	2.12
	SIR	1.33	1.57	0.69	2.12	−2.30	−2.50	12.46
	LIR	–	–	–	–	–	–	–
	UR	1.77	1.74	0.19	2.18	1.38	0.47	2.60

Table 15
GOLD: Unrestricted cointegration rank test (trace & maximum Eigen value).

Country	Hypothesis	Trace	Critical Value (0.05)	Prob*	Max-Eigen	Critical Value (0.05)	Prob*
Australia	None*	135.33	107.34	0.00	53.09	43.41	0.00
	At most 1*	82.24	79.34	***0.03***	38.28	37.16	***0.03***
	At most 2	43.95	55.24	0.33	22.97	30.81	0.33
	At most 3	20.98	35.01	0.64	13.86	24.25	0.60
	At most 4	7.11	18.40	0.77	6.51	17.15	0.76
	At most 5	0.59	3.84	0.44	0.59	3.84	0.44
Japan	None*	182.70	150.55	0.00	55.95	50.59	0.01
	At most 1*	126.75	117.70	***0.01***	42.74	44.50	***0.07***
	At most 2	84.00	88.80	0.10	35.26	38.33	0.10
	At most 3	48.74	63.88	0.47	19.31	32.12	0.70
	At most 4	29.43	42.91	0.53	15.88	25.82	0.55
	At most 5	13.56	25.87	0.69	8.09	19.39	0.81
China	None	116.61	117.70	0.06	42.48	44.49	0.08
	At most 1	74.14	88.80	0.35	25.83	38.33	0.61
	At most 2	48.31	63.88	0.49	22.56	32.11	0.45
	At most 3	25.74	42.91	0.75	12.60	25.82	0.83
	At most 4	13.13	25.87	0.72	7.63	19.38	0.85
	At most 5	5.49	12.51	0.52	5.49	12.51	0.52
India	None	84.59	95.75	0.23	32.26	40.07	0.28
	At most 1	52.32	69.81	0.53	26.30	33.87	0.30
	At most 2	26.01	47.85	0.88	14.03	27.58	0.82
	At most 3	11.99	29.79	0.93	7.11	21.13	0.94
	At most 4	4.88	15.49	0.82	2.78	14.26	0.96
	At most 5	2.09	3.84	0.14	2.09	3.84	0.14

Source: All of the aforementioned measures were calculated using monthly time series data obtained from the sources listed in Table 1.

Table 16
SILVER: unrestricted cointegration rank test (trace & maximum Eigen value).

Country	Hypothesis	Trace	Critical Value (0.05)	Prob*	Max-Eigen	Critical Value (0.05))	Prob*
China	None*	121.21	117.70	***0.03***	40.83	44.49	0.12
	At most 1	80.38	88.80	0.17	24.538	38.33	0.70
	At most 2	55.84	63.88	0.19	21.59	32.11	0.52
	At most 3	34.24	42.91	0.27	15.33	25.82	0.60
	At most 4	18.92	25.87	0.28	10.89	19.39	0.52
	At most 5	8.03	12.52	0.24	8.026	12.52	0.25
India	None*	120.23	117.70	***0.03***	43.90	44.49	***0.05***
	At most 1	76.33	88.80	0.28	29.48	38.33	0.35
	At most 2	46.84	63.88	0.56	19.82	32.11	0.66

(*continued on next page*)

Table 16 (*continued*)

Country	Hypothesis	Trace	Critical Value (0.05)	Prob*	Max-Eigen	Critical Value (0.05))	Prob*
	At most 3	27.01	42.91	0.68	15.48	25.82	0.59
	At most 4	11.53	25.87	0.84	7.83	19.38	0.83
	At most 5	3.69	12.51	0.78	3.69	12.51	0.78

Source: All of the aforementioned measures were calculated using monthly time series data obtained from the sources listed in Table 1.

Table 17
PLATINUM: unrestricted cointegration rank test (trace & maximum Eigen value).

Country	Hypothesis	Trace	Critical Value (0.05)	Prob*	Max-Eigen	Critical Value (0.05)	Prob*
USA	None*	199.29	150.55	0.00	70.87	50.59	0.00
	At most 1*	128.42	117.70	***0.00***	50.69	44.50	***0.00***
	At most 2	77.74	88.80	0.24	30.28	38.33	0.31
	At most 3	47.46	63.87	0.53	21.27	32.12	0.55
	At most 4	26.19	42.91	0.72	13.43	25.82	0.76
	At most 5	12.75	25.87	0.75	7.64	19.39	0.85
	At most 6	5.11	12.51	0.58	5.11	12.52	0.58
UK	None*	163.77	125.61	0.00	58.87	46.23	***0.00***
	At most 1*	104.90	95.75	***0.01***	37.58	40.07	0.09
	At most 2	67.31	69.81	0.07	34.05	33.87	0.04
	At most 3	33.25	47.85	0.54	18.84	27.58	0.43
	At most 4	14.41	29.79	0.81	10.97	21.13	0.64
	At most 5	3.43	15.49	0.94	3.23	14.26	0.93
	At most 6	0.20	3.84	0.65	0.20	3.84	0.65
China	None*	144.26	117.70	0.00	43.42	44.49	0.06
	At most 1*	100.83	88.80	0.00	36.53	38.33	***0.07***
	At most 2*	64.29	63.88	***0.04***	23.97	32.11	0.35
	At most 3	40.32	42.91	0.08	17.99	25.82	0.37
	At most 4	22.32	25.87	0.13	17.68	19.38	0.08
	At most 5	4.63	12.51	0.65	4.636	12.51	0.64

Table 18
PALLADIUM: unrestricted cointegration rank test (trace & maximum Eigen value).

Country	Hypothesis	Trace	Critical Value (0.05)	Prob*	Max-Eigen	Critical Value (0.05)	Prob*
Australia	None*	115.29	117.70	***0.07***	47.80	44.49	***0.02***
	At most 1	67.48	88.80	0.60	29.99	38.33	0.32
	At most 2	37.49	63.87	0.91	15.58	32.11	0.92
	At most 3	21.90	42.91	0.91	13.30	25.82	0.77
	At most 4	8.60	25.87	0.97	4.98	19.38	0.98
	At most 5	3.61	12.51	0.79	3.61	12.51	0.79
USA	None*	148.54	139.27	***0.01***	55.92	49.58	***0.00***
	At most 1	92.62	107.34	0.30	33.73	43.41	0.37
	At most 2	58.88	79.34	0.61	27.91	37.16	0.38
	At most 3	30.97	55.24	0.90	17.61	30.81	0.73
	At most 4	13.35	35.01	0.97	8.80	24.25	0.95
	At most 5	4.55	18.39	0.95	3.94	17.14	0.96
	At most 6	0.60	3.84	0.43	0.60	3.84	0.43

Source: All of the aforementioned measures were calculated using monthly time series data obtained from the sources listed in Table 1.

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