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CAFÉ WORKING PAPER NO.28

CAFÉ RESEARCH CENTRE

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March 2024

Market Efficiency Perspective of Precious Metals: Evidence from Developed and Emerging Economies

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Abstract

This study examines the weak-form market efficiency of international precious metals markets (Gold, Silver, Platinum, and Palladium) using data from 9 domestic markets in their local currencies - rather than a US Dollar price as in most previous studies. We do this by using the Automatic Portmanteau test, Automatic Variance Ratio test, Autoboot Variance ratio test and Generalized Spectral Shape test to look at their evolving efficiency over time.

The findings of this study suggest that market efficiency for four precious metals varies over time across both developed and emerging markets. The variation in market efficiency could be attributable to cyclical developments due to technology and the economic cycle. That they do not tend to efficiency together indicates that these markets are fragmented and not as interconnected as might have been assumed due to a variety of factors such as local regulations, market complexity, and differences in the market structure in each country.

Keywords: Adaptive markets hypothesis, Martingale difference hypothesis, Market Efficiency, Precious Metals, Gold.

JEL Codes: G4, G10, G11, G12, G15

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1 Introduction

The purpose of this study is to explore the weak-form market efficiency of international precious metals and determines whether these metal markets demonstrate the efficiency across developed and emerging markets. Numerous studies, such as Charles et al. (2015) investigate the market efficiency of gold, silver, and platinum but with a focus on US markets. A gap exists in the literature to investigate this issue for other geographical precious metals markets in developed and emerging economies focusing on the domestic price of the metals. In addition, Shahid et al. (2019) uses the Adaptive Market Hypothesis (AMH) to predict gold, silver, and metal returns over time. However, their five-year sample and single market emphasis limit their results. They proposed that conducting a rolling window analysis would be a better approach to investigate the concept of AMH.

To broaden our understanding of AMH and measure market efficiency, we explore and update the methodologies used to analyse market efficiency in various developed and emerging markets over long periods. Palladium is an additional metal that we include in our analysis. In addition, we study the traded local currency prices for these assets rather than the US Dollar gold price converted into local currency to allow for local market heterogeneities. For example, we use data on domestic markets in China through data from the Shanghai Gold Exchange and Australia from the Perth Mint (see Table 1). While gold is traded internationally in many markets and in different ways (Exchange, Over the Counter trading (OTC), Bar and Coin), its price discovery is dominated by two markets: London where most OTC trading happens and the New York Futures markets (Lucey, Larkin, and O'Connor 2014). However, market frictions do exist locally, meaning that the price in Shanghai is not simply a function of the US Dollar price and the exchange rate—instead, a premium usually exists between these two prices and the traded price in China[5]. This friction means that questioning the efficiency of precious metals in different currencies is essential to address.

Precious metals play a vital role in portfolio selection and management due to their distinct properties, which are seen as hedges against a variety of risks (Emmrich and McGroarty,2013). Over the last few decades, investors have increased their holdings of precious metals, and empirical evidence suggests these metals have the ability to hedge against inflation and economic downturns in a way that the more procyclical base metals cannot (Lucey et al., 2016). Moreover, these metals have a remarkable ability to improve a portfolio for investors in terms of its higher reward-to-risk ratio (Hillier et al., 2006; Daskalaki and Skiadopoulos,2011).

Gold and silver are the most prominent precious metals with a 6,000-year history as being precious to humans (O'Connor, 2023). Among four precious metals, the trade in these two was especially visible during the Asian financial crises of 1997-1999 and global financial crises of 2007-2008, where the volume of precious metal holdings increased significantly (Figuerola-Ferretti and McCrorie,2016). However, the properties of platinum and palladium have attracted much attention in recent years as they offer different returns and volatility directions in times of crisis (Arouri et al.,2012). For instance, Morales and Andreosso O Callaghan (2011) show that silver, platinum, and palladium outperformed other major financial markets during the global financial crisis. These white precious metals have started to outperform as an investment commodity once the silver ETF was introduced in April 2006, followed by platinum and palladium ETFs in 2010 (Vigne et al., 2017).

To test the market efficiency, Charles et al. (2015) examine gold, silver, and platinum using the automatic portmanteau and variance ratio tests, but only for the US market. In this paper, we extend and modernize the methodologies applied to this question across developed and emerging markets for extended periods.

[5] See https://www.gold.org/goldhub/data/gold-premium for details.

For robustness, we test market efficiency using the martingale difference hypothesis (MDH) across developed and emerging markets using three more recent techniques. These include the Autocorrelation and Spectrum based tests for MDH, namely, (i) the automatic variance ratio test (AVR) as proposed by Choi (1999) further tested by Kim et al. (2011), (ii) the automatic portmanteau test (AQ) of Escanciano and Lobato (2009), the Wild Bootstrap Automatic Variance Ratio test by Kim (2009), and (iii) Generalized Spectral test by Escanciano and Velasco (2006), an improved version of the Durlauf (1991) test. This is the first time the Generalized Spectral test is used to examine precious metals' linear and non-linear autocorrelation structures across developed and emerging economies."

To gain deeper insight, we also examine the predictability of returns over time using a two-year rolling window approach of each test statistic across an extended sample period to determine the variability in return predictability over time for these metals and markets. Thus, we can observe the time-varying predictability of precious metals returns and determine if any return predictability patterns vary over time. This research employs sample data starting on February 1, 1968, to maximize the power of our tests. However, the sample data length varies across metals and markets, for example, data for the Chinese market does not become available until 2002.

The paper is structured as follows: Section 2 reviews the background on precious metals and adaptive markets hypothesis. Section 3 describes the methodology and limitations and Section 4 the dataset. Section 5 provides the result and evaluates the empirical findings. Section 6 concludes.

2 Literature Review

Numerous studies have found that uncertainty in market conditions, such as changes in international institutions and macroeconomic factors (i.e., variations in exchange rates, the business cycle, the monetary environment, and financial market sentiment - see Rana and O'Connor (2023) for analysis of this in an international context) and different global-political factors may affect the market efficiency and other market features (see for example, Kaufmann and Winters, 1989; Hood and Malik, 2013). Below we review the literature on Market Efficiency and the Adaptive Markets hypothesis in the context of precious metals markets.

2.1 Adaptive Market Hypothesis (AMH)

The theory of Efficient Market Hypothesis (EMH) has provided insight into the role of information to affect price change within financial markets – dominating the literature over the last 30 years. It states that investors, in perfectly competitive markets cannot beat the market as companies always trade securities at their fair value (Fama, 1970). However, empirical studies yield conflicting results regarding the validity of this theory, leading to an ongoing dispute between the EMH and behavioral finance schools of thought. Some studies provide evidence that corroborate the EMH (Ayadi and Pyun, 1994; Stachowiak, 2004). However, several other studies have also highlighted the deviation from the random walk (Al-Ajmi and Kim, 2012; Squalli, 2006) and the possibility of effective investment techniques (Asem and Tian, 2010; Shi and Zhou, 2017).

Initially, Fama (1988) argued that EMH was still valid because the abnormalities reported in multiple studies were not stable and vanish when changes were made to the model, sample, or data frequencies. However, subsequently, behavioral finance challenged EMH and highlighted that investors are not always rational, and stocks do not always trade at their fair value when they are financially unstable (Lo, 2004). Therefore, Lo (2004) proposed a new framework called an Adaptive Market Hypothesis (AMH) to reconcile market efficiency (based on well-known principles of evolution, adaptation, competition, and natural selection) with financial interactions. AMH brings together the concepts of behavioral finance and the EMH of Fama (1970) in one package. Thus, the adaptive market hypothesis (AMH) considers both these contradictory views to explain investor choices and market behavior.

The AMH's primary practical application in finance is in determining the optimal time to adopt lucrative investment strategies as profit opportunities grow over time. Consistent with an evolutionary market approach, opportunities for extraordinary profits appear, but quickly vanish. Profitable strategies emerge in a certain market setting. Unlike the EMH, which contends that active management is useless and cannot do better than "buy and hold", the AMH defends active portfolio management (Lekhal and El Oubani,2020). Testing the EMH often leads to an unrealistic situation, in which the market is either perfectly efficient or inefficient, depending on the outcome of the test. However, in the case of AMH, there is a possibility that the market will demonstrate an exit from the level of perfect efficiency, depending on numerous market conditions (Charles et al., 2015). AMH's concept is established by the integration of evolutionary principles with the idea of bounded rationality (Simon, 1955). An investor is said to be bounded rational, whose priority is satisfaction as compared to optimal behavior.

2.2 Weak-Form of EMH

The weak-form of EMH has been widely tested using the martingale difference hypothesis (MDH), which states that the current price is the best forecast of future price (i.e. asset prices are martingale) (Escanciano and Velasco,2006). Therefore, traders are unable to take use of historical information in order to generate a return that exceeds the level that is consistent with the risk they are willing to incur (Fama, 1970).

Numerous studies have found the weak-form efficiency of financial assets, which was initially related to whether or not stock prices are randomly created in the first place (Ntim, 2012; Smith, 2002). Earliest literature include studies by Tschoegl (1978); Solt and Swanson (1981) have investigated the weak-form efficiency of the gold market, even though their findings were varied. For example, Tschoegl (1980) empirically investigated the price of gold from the perspective of weak-form efficiency, testing a series of twice-daily prices for gold to determine whether successive price changes are independent or not. If prices are not independent, investors could use the knowledge of the dependence to earn trading profits. Tschoegl (1980) and Ho (1985), applied the same approach in the London gold market, where gold is used as a financial asset. Tschoegl and Ho found weak efficiency in the gold market because investors cannot predict gold price changes using past information.

Solt and Swanson(1981) provided an in-depth analysis of the weak form efficiency for the leading precious metals (gold and silver markets) and discussed the relationship between gold and silver as an investment asset. They suggested that trading in gold and silver is more like a speculative activity than an investment activity. However, due to the non-stationarity found in the data, it is not clear whether to use metal prices in buy and sell decisions; it does not seem like investors can easily place any metal in a conventional investment system. Moreover, they found that gold and silver received excellent returns during the past decade, but this does not guarantee similar future results.

Therefore, trading in the metals seems to pose a significant risk, not the least of which is the likelihood of a shift in the process causing price fluctuations for gold and silver. Beckers (1984) test the weak-form efficiency in the daily gold price return series of the Dutch and UK gold markets and fail to reject weak-form efficiency in both gold markets. Monroe and Cohn (1986) analyzed monthly price series of gold futures traded on the Chicago Mercantile Exchange from 1976 to 1982 and observed that gold price series weak-form efficiency changes over time. This means profits were regularly available if one took a position focused on returning to equilibrium. While the evidence is consistent with a marked trend towards efficient pricing in future markets, significant deviations from efficiency occur frequently.

It is worth noting that most of the studies conducted in the 1970s were based on the application of more basic statistical techniques (e.g., auto-correlation, runs, and unit root tests), thus their findings could be questionable. Additionally, the core weakness of these techniques is that they assume linearity in financial asset price return series (Ntim, 2012), which however result in false rejection (or acceptance) of the random walk hypothesis (Luger, 2003; Wright, 2000). However, market conditions have changed over time because of the enhancement in technology, advancement in econometric techniques and mathematical modelling itself that has enabled academics to take new look at the findings of the model. Recent studies use more powerful and modern statistical techniques such as chaos, fractals, neural networks, variance-ratios, automatic variance ratio test, automatic portmanteau test and ARCH–GARCH models (Pierdzioch et al., 2014; Charles et al., 2015).

However, the findings of recent studies using modern statistical techniques are still generally mixed (Basu and Clouse,1993; Baur,2013. For instance, Pierdzioch et al.(2014) used the real time forecasting approach to investigate whether publicly available information on macroeconomic variables helps to forecast out-of-sample monthly excess returns on investing in gold. They find that the London gold market exhibits weak-form efficiency. Conversely, Shafiee and Topal (2010) test a long-term trend reverting jump and dip diffusion model with monthly spot gold prices from 1968 to 2008. Their model rejects the random walk hypothesis in the UK gold markets. O'Connor et al. (2015) provide a literature survey of this issue for gold and Vigne et al. (2017) do the same for the three precious white metals.

Arouri et al. (2012) questioned the efficiency of platinum and palladium markets by assessing the weak form of the EMH. Using a 12-year time horizon, they examined the link between spot and futures prices for both Platinum Group Metals (PGMs) and discovered that both have a long- run equilibrium pricing relationship. However, lagged values of spot price change aid in predicting both, and lagged platinum futures price changes also aid in explaining its spot price variations. The convenience yields of gold and silver have considerable effects on the platinum and palladium returns, according to Chng and Foster (2012). Moreover, the convenience yields of platinum and palladium appear to be unaffected by any of the precious metals. They also stated in their limitation that the issue of efficiency in these two metals markets is ripe for further investigation. Platinum and Palladium have been found to provide significant diversification benefits in the con- text of investment portfolios.

A study by Hillier et al. (2006) revealed that platinum's low correlation with financial markets provides a safe haven and diversification at the same time. Golds safe haven characteristic has been questioned by He et al. (2018) who argue that it is an always hedge rather than switching to a safe haven at times. Behavioral finance studies on these two metals, such as Lucey and Dowling (2011) have investigated the impact of investor mood on the price of platinum and palladium. They found that Mondays have a large negative impact on the palladium market, but other than that, the mood proxies tested indicated that the palladium market was a rationally determined market, in contrast to many of the findings for the equity markets. One possible explanation for this is the higher scale and, as a result, the probable enhanced sophistication of investors in precious metals markets relative to equity investors.

Using rediscovered daily gold price data from the London Gold market pre-1968, O'Connor and Lucey (2023) look at the efficiency of the market during periods of the gold standard and freely floating gold prices. They find evidence that this market exhibits weak form efficiency at its beginning in 1919 but then find in the second period of freely floating prices, from 1931-39, that the actions of hoarders reduced the gold market's efficiency.

Charles et al. (2015) find that the degree of predictability of gold, silver, and platinum is highly dependent on the prevailing economic and political conditions. They analyze the weak-form efficiency using the automatic Portmanteau test of Lobato et al. (2001) due to the existence of conditional heteroscedasticity. Furthermore, they find that among all three precious metals, gold shows the highest degree of market efficiency. In our paper, we also employ the AQ (automatic portmanteau) test to examine the unknown forms of conditional heteroskedasticity of precious metal returns.

Zunino et al.(2011) analyzed the predictability in commodity markets by using a novel approach which has derived from information theory. Their study shows the efficiency ranking, finding silver, copper, and cotton to be the most efficient commodities. Similarly, Wang et al. (2011) observed the gold market using the multifractal detrended fluctuation analysis and reported that the market becomes more efficient in time, especially after 2001.

Hence, to investigate how the degree of return predictability has evolved, depending on economic, political, and financial events. We use a moving sub-sample window approach, a method used by Charles et al.(2015) and Kim et al.(2011). It is an approach that is mostly used in time series regression; the approach involves conducting repetitive regressions, with sub-samples of our original full sample.

3 Methodology

We test market efficiency of four leading precious metals in the metals markets using the martingale difference hypothesis (MDH) across different countries. This study adopts the most recent techniques in both the Autocorrelation based and Spectrum based tests for MDH, namely, (i) the automatic variance ratio test (AVR) of Choi (1999), which was also tested by Kim (2009); Kim et al. (2011). In addition, it includes the confidence interval that displays the degree of uncertainty associated with the return predictability. (ii) the automatic portmanteau test (AQ) of Escanciano and Lobato (2009), the Wild Bootstrap Automatic Variance Ratio test by Kim (2009), and (iii) Generalized Spectral test by Escanciano and Velasco (2006).

With the exception of Sensoy et al.(2015) and Charles et al. (2017), who performed a time-varying analysis with a rolling sample by applying the permutation entropy approach, none of the previous studies have employed time-varying measures of return predictability to examine the martingale difference hypothesis (MDH), our paper aims to fill this gap, we also employed Kim (2009) wild bootstrap automatic variance ratio test and Escanciano and Lobato (2009) to test for the martingale difference sequence (MDS) property, which is robust to non-normality and conditional heteroscedasticity. Using a moving sub-sample window technique, we investigated how the degree of return predictability or market efficiency has changed over time, because of changes in the economy, politics, and financial events.

To test time-varying predictability of return, we use the 2-years moving sub-sample window approach used by Charles et al. (2011) consisting of approximately 524 daily observations. This sample size is sufficiently large to guarantee the desirable size and power properties of the tests employed. The two-year window is also appropriate for catching the impact of rising market conditions. The first sub-sample window covers the 1968-to-1969-time frame. The window then moves forward by one month, covering the period from 1968 to 1970. The cycle continues until the data set ends. Applying this approach, we get monthly measures of predictability of the time-varying return. Therefore, periods or episodes with a high degree of return predictability with statistical significance are established, which are linked to events and shocks. It should be noted that the use of a moving sub-sample window approach in this paper is not intended for multiple experiments but is implemented as a way of calculating the degree of predictability of return over time. It is also adequate preventative protection against data snooping (Hsu and Kuan,2005).

3.1 Measure of return predictability

This section provides brief descriptions of various statistical tests for return predictability adopted in this paper.

The MDH is the best predictor of future values of a time series because it assumes that current price is the best estimate of future price (i.e., asset prices are martingale). It plays a vital role in different economic models; especially where expectations are supposed to be rational (Escanciano and Lobato,2009). Empirical literature of MDH suggested different methodologies ranging that are based on both linear and non-linear dependencies (autocorrelations). Such as for the linear measures portmanteau test by Ljung and Box (1978) and variance ratio test by Lo and MacKinlay (1988). Traditionally, the portmanteau test of Ljung and Box(1978) and variance ratio test of Lo and MacKinlay (1988) have been extensively used in the empirical finance for the evaluation of asset return predictability. However, both these tests failed to perform in small samples, particularly under conditional heteroskedasticity extensively observed in financial data. Moreover, they need ad hoc choices of the lag length or holding periods that lead to undermine their small sample properties. Lately, more sophisticated techniques have been introduced that possess more power and size properties under each category. Numerous studies have contributed to these tests. For ex- ample, Lobato et al. (2001) improved portmanteau test and enhanced the small sample properties under conditional heteroskedasticity.

In this paper, we have adopted the pre-eminent new linear measures; for instance the automatic portmanteau (AQ) test of Escanciano and Lobato (2009) and the automatic variance ratio (AVR) test of Kim (2009). To overcome the issue of selecting the lag length or holding period in an ad-hoc way Escanciano and Lobato (2009) suggested the automatic portmanteau (AQ) test. In this test, based on fully data dependent procedure the selection of lag length is completely automatic. Whereas Kim (2009) put forward the automatic variance ratio (AVR) test in which the optimal holding period is automatically selected. However, to account for non-linear dependencies (autocorrelation), we employ the generalized spectral (GS) test of Escanciano and Velasco (2006) to detect the possible nonlinear dependence in precious metal returns. This test has the capacity to observe both linear and nonlinear dependence. Furthermore, this test contains wild bootstrapping method, in a similar manner to the AVR test discussed earlier, where the p-value of the test can be obtained. In other words, if the p- value is less than 0.05, the hypothesis of no (linear and nonlinear) return predictability is rejected at the 5% level of significance.

Charles et al. (2011) reported that under a wide range of conditional heteroskedastic asset returns in small samples, AVR and AQ tests show desirable results, whereas the GS test performs better under nonlinear dependence. Moreover, due to the increasing propagation of tests, Charles et al. (2011) conduct a Monte Carlo experiment to note the similar power properties of alternative tests of MDH and reported that wild bootstrap AVR test shows the highest power against linear dependence. The wild bootstrapping is resampling technique which is appropriate to the data with unknown forms of conditional and unconditional heteroskedasticity (see Mammen (1993); Flachaire (2001)). In addition, Gonccalves and Kilian (2004) suggested that this method is very useful for solving econometric glitches. Kim (2006) also proposed the wild bootstrap test and found that it has a great tendency to improve small sample properties of variance ratio tests as compared to their alternatives in most circumstances. Thus, in this paper, we use both the wild bootstrap AVR and GS tests for the MDH.

3.2 Automatic portmanteau test (AQ)

Choi (1999) proposed the automatic variance ratio (AVR) test, which determines the optimal value of utilizing a wholly data-dependent process. Moreover, Choi (1999) demonstrated small sample properties of the AVR test when the return follows an *iid* process, but its properties when conditional heteroskedasticity is unknown. However, one of the most significant disadvantages of the AVR test is that positive and negative correlations may cancel one other out, resulting in an inaccurate AVR test statistic. The automatic portmanteau test (AQ), which is an asymptotic test based on the squared correlation coefficients, overcomes this issue (Kim et al., 2011). The prime test of market efficiency is the test for serial correlation returns. It has held a significant role in the history of statistical analysis of economic time series Yule (1926).

In the early 90's Robinson (1991) was focused on modifying the traditional tests for serial correlation. Robinson emphasized the importance of establishing tests for serial correlation with the two main features of economic time series, that has been overlooked since its inception. Firstly, the presence of nonlinear dependence in the financial time series, mainly under conditional heteroskedasticity. Secondly, the existence of strong dependence which exists in macroeconomic time series. Various statistical tests were proposed for serial correlation in various contexts. In various kind of his tests, he focused on the utilization of martingale difference assumptions and the Lagrange Multiplier (LM) principle. Hence, Robinson(1994) and Lobato and Robinson (1998) used the LM principle to test for long memory. Godfrey (1978) also employed the same principle - LM to test the serial correlation in regression models with lagged dependent regressors.

However, in econometrics the Portmanteau Box–Pierce test is considered the most dominant approach for testing the serial correlation. It is the statistical approach in which the sample size times the sum of squares of the first sample autocorrelations and then compared with critical values from a chi-square distribution. This test has been marginally improved and used by some researchers such as Davies et al. (1977); Davies and Newbold (1979); Ljung and Box (1978); Li and McLeod (1981) to enhance its finite sample performance.

There are still two key limitations in the Portmanteau Box–Pierce test: (i) theoretically this test was developed under the independence assumption; (ii) practically, the selection of the employed number of autocorrelation p is random. Lobato et al. (2002) addressed the first limitation of Portmanteau Box–Pierce test and the extension of portmanteau statistics allows for non-linear dependence. Moreover, the significance of bootstrap suggested by Horowitz et al. (2006) for examining the critical values in the form of general weak dependence conditions. The issue regarding the second limitation sorted out by Escanciano and Lobato(2009) as they suggested a portmanteau statistic that allows for nonlinear dependence, and where the parameter p is not fixed but selected automatically from the data. Similarly, one of the main limitation of smooth test is the random selection of p as discussed by Neyman (1937) and this portmanteau test have all the important characteristics in which the data choose the order p by automatically adapting to the order of the serial correlation present in the data.

The portmanteau test is extensively discussed in the financial literature to test for $H_0 : \rho_j = 0$ for all $j = 1,....p$, especially when the metal return is subject to unknown forms of conditional heteroskedasticity (Kim et al.,2011). The actual form of portmanteau test statistic is discussed by Charles et al.(2015) and it can be written as;

$$Q_\rho = T \sum_{i=1}^{\rho} \hat{\rho}_i{}^2 \quad \textbf{(1)}$$

In equation 1, where Q_p is the portmanteau test statistic $\hat{\rho}(i)$ is the sample of auto correlation of Y_t of order i. When Y_t shows conditional heteroscedasticity. Lobato et al. (2001) suggested the utilization of a robust portmanteau test statistic of the following form which is also highlighted by Charles et al. (2015) and Kim et al. (2011).

$$Q_p = T \sum_{i=1}^{p} \hat{\rho}_i{}^2 \quad \textbf{(2)}$$

In equation 2, where $\hat{\rho}_i{}^2 = \hat{\gamma}_i{}^2/\tau^2$; $\hat{\gamma}_i{}^2$ is the estimator for the autocovariance of metal return of order i, and τ^2 the autocovariance of squared metal returns. Escanciano and Lobato (2009) used the robust portmanteau test with automatic lag selection, where the optimal value of p is fixed by a fully data-dependent procedure. The test can be written as follows:

$$AQ = Q_{\tilde{p}}{}^* = T \sum_{i=1}^{\hat{p}} \tilde{\rho}_i{}^2 \quad \textbf{(3)}$$

In equation 3, where $\tilde{p}$ is the ideal lag order to be determined by a cooperation between Akaike's information criterion and the Bayesian information criterion. This AQ test statistic asymptotically follows the chi-squared distribution with one degree of freedom. Moreover, if the value of AQ is greater than 3.84 then the null hypothesis of no return autocorrelation is rejected at the 5% level of significance.

3.3 Automatic variance ratio test (AVR)

The variance ratio (VR) test was extensively used in empirical finance to assess the weak form efficiency of financial markets. There are several empirical studies (Kim and Shamsuddin, 2008 and Belaire-Franch and Opong, 2005) that have used the variance ratio test on financial market efficiency; and Patro and Wu(2004) on financial return predictability. The VR test, proposed initially by Lo and MacKinlay (1988) examined the random walk hypothesis for weekly stock market returns. Subsequently, the variance ratio test has gone through various improvements since its inception. In statistics, VR test is fascinating for the researchers and known to have ideal attributes under certain conditions, as shown in Faust (1992). Chow and Denning(1993) extended the variance ratio methodology of Lo and MacKinlay (1988) with slight modification for testing multiple variance ratios. Liu and He (1991) and Yilmaz(2003) provide the significant application of variance ratio tests. These tests are asymptotic tests having small sample deficiencies.

Therefore, Wright (2000) suggested the variance ratio test using the ranks and signs of returns for examining whether the stock market and exchange rate returns are serially uncorrelated at all leads and lags. In addition, he proposed that ranks and signs are an effective tool in non-parametric statistics, in which data is dependent on sorts of ranking rather than numbers. Similarly, other contributions include the sub-sampling of Whang and Kim (2003), wild bootstrap tests of Kim (2006) and power transformed test of Chen and Deo (2006). Furthermore, all these proposed VR tests do not rely on asymptotic approximations and suggested that these VR tests display small sample properties more than the existing VR tests.

Charles and Darne (2009) applied the conventional individual and multiple VR test with all improved versions such as - power-transformed statistics, rank and sign tests, sub-sampling, and bootstrap methods of variance ratio tests. In this study, we have taken into account three *leading emerging markets* (i.e., China, Mexico, India) and compare them with the developed markets (i.e., Australia, United Kingdom, United states, Switzerland, Japan and Hong Kong). Our aim is to assess whether precious metals markets are weak form efficient (or not). We focus on gold, silver, platinum, and palladium.

In our model, we employed the automatic variance ratio test of Kim (2009) which extends the earlier work of Choi (1999) where the choice of parameter is regulated automatically using a data- dependent procedure. In addition, we adopt the wild-bootstrapped AVR test of Kim (2009), which significantly improves the small sample properties of AVR test.

Using Kim et al. (2011) notation, the variance ratio test statistic can be written as weighted sum of autocorrelation of metal returns, namely:

$$V(k) = 1 + 2 \sum_{j=1}^{k-1}\left(1 - \frac{j}{k}\right)\rho_j \quad \textbf{(4)}$$

Equation 4 shows the Variance Ratio test, where ρ_j is the jth order autocorrelation of the returns and k is the holding period. Therefore, V(k) can be evaluated as

$$VR(k) = 1 + 2 \sum_{j=1}^{k-1}\left(1 - \frac{j}{k}\right)\hat{\rho}_j \quad \textbf{(5)}$$

where ρ_j is calculated with the help of $\rho\hat{}_j$ estimator and k indicates the holding period.

The main characteristic of the variance ratio test is that if asset return is purely random and the variance of k-period return is k times the variance of one period-return. Thus, the variance ratio $VR(k)$ can be defined as the ratio of $1/k$ times the variance of k-period return to that of one-period return, which should be equal to one for all k. For the application of variance ratio test, the choice of holding period k (holding period) is vital as it entails rather an ad hoc and arbitrary choices but with the slight statistical justification of the value of k (Kim, 2009).

However, Choi (1999) proposed an automatic variance ratio test (AVR) along with improvements, in which the optimal value k is chosen with the help of entirely dependent procedure of Andrews (1991). Choi (1999) found the considerable results of the AVR test in small sample properties, especially when the returns are completely unknown in the form of conditional heteroscedasticity. The AVR test statistics is estimated as:

$$AVR(k) = T/\hat{k}[VR(\hat{k}) - 1]/\sqrt{2^d} \rightarrow N(0,1) \tag{6}$$

One of the primary drawbacks of the AVR test in equation 5 is that it may result in erroneous inferences, particularly when employed on small samples with conditional heteroscedasticity of the unknown form (Kim, 2009). Moreover, the AVR test can be significantly improved under conditional heteroscedasticity, by using the wild bootstrap of Mammen (1993). Gonccalves and Kilian (2004) proposed that wild bootstrap is highly effective for econometric challenges, for instance, when the data has unknown forms of conditional and unconditional heteroskedasticity. Therefore, we use the AVR (see equation 6) to investigate the weak form of efficiency of metal markets and assessing the predictability of metals returns. Kim (2006, 2009) also suggested the wild bootstrapping approach to obtain reliable conclusions in the presence of conditional heteroscedasticity and non-normality in small samples. Subsequently, Kim et al. (2011) used a Monte Carlo experiment to demonstrate that the wild bootstrapping approach of Kim (2006, 2009) had favorable small sample features.

3.4 Generalized Spectral Test

AVR and AQ tests are based on serial correlation in which we illustrate the degree of similarity between a given time series and a lagged version of itself over successive time intervals. In addition, the above two tests have a capability to detect the linear dependance only. However, generalised spectral (GS) test captures both linear and non-linear dependencies in asset returns Escanciano and Velasco (2006).To see the more details of the test, interested readers are pointed to Escanciano and Velasco (2006); Escanciano and Lobato (2009). As a result, we employed the GS test to capture non-linear dependencies in the returns on precious metals prices across developed and emerging economies. Escanciano and Velasco(2006) proposed the use of a generalised spectral distribution function of the following form for empirical tests;

$$H(\lambda, x) = \gamma(x)\lambda + 2\sum_{j=1}^{\infty} \gamma_j\,(x)\,\frac{sin(j\pi\lambda)}{j\pi} \tag{7}$$

where λ is a real number between 0 and 1. Equation 7 contains a sample estimate of the function, which is represented as;

$$H(\lambda, x) = \gamma(x)\lambda + 2\sum_{j=1}^{\infty}(1 - \tfrac{j}{T})\tilde{\gamma}_j\,(x)\,\frac{sin(j\pi\lambda)}{j\pi} \tag{8}$$

In equation 8, where $\gamma 0(x) = \left((T - J)^{-1}\right)\sum_{t=1+j}^{T} Y - \bar{Y}_{T-J}\right) e^{ixY_{t-j}}$ and $\bar{Y}_{T-J} = (T - J)^{-1}\sum_{t=1+j}^{T} Y_t$. As a result, the null hypothesis for the function of generalized spectral distribution is $H_o(\lambda, x) = \hat{H}\ (\lambda, x) = \gamma_0(x)\lambda$ where the test statistics is

$$ST\ (\lambda, x) = (0.5T)^{1/2}\{\bar{H}(\lambda, x) - H_0\ (\lambda, x)\} \tag{9}$$

Then, to evaluate S_T for all possible combinations of λ and x as shown in equation 9, Escanciano and Velasco (2006) employ the Cramer-von Mises norm to derive the following test statistics:

$$D_T{}^2 = \sum_{j=1}^{T-1} \frac{(T-j)}{(j\pi)^2} \int R \backslash \hat{\gamma} j x \backslash^2 W(d\,x) \tag{10}$$

In equation 10, W() is a weighting function. Escanciano and Velasco (2006) calculate the GS test statistics as a weighting function based on the standard normal distribution.

$$D_T{}^2 = \sum_{j=1}^{T-1} \frac{(T-j)}{(j\pi)^2} \sum_{t=j+1}^{T} \sum_{S=j+1}^{T} exp(-0.5(Y_{t-j} - Y_{s-j})^2 \quad \textbf{(11)}$$

Escanciano and Velasco (2006) proposed that the wild bootstrapping approach is used to construct the GS test statistic in our finite samples of precious metals prices because this statistic's standard distribution is not asymptotic (markets). For each market across our estimation period, we obtain the p-values of the GS test statistics and plot them on a line graph for each market. This test provides desired results, primarily when used with the AVR and AQ tests. Using the AVR and AQ tests, for example, a failure to reject the null hypothesis but a rejection of the null hypothesis using the GS test will indicate evidence of nonlinear autocorrelations that market players can exploit to achieve greater performance returns.

4 Data Description

This study employs historical data on the daily prices of the four precious metals (gold, silver, platinum, and palladium). We examine everyday spot prices of four precious metals for two categories of economies: developed and emerging markets. Developed markets are those markets that are considered economically and financially stable. Moreover, these economies have a high degree of regulations and a relatively high economic development, a free exchange, and strong liquidity on their debt and equity markets, such as the US, UK, Japan, Hongkong, Switzerland, and Australia. Emerging markets are economies that display some of the developed economies' traits but do not have the same level of regulation, oversight, or market efficiency that developed markets have—for instance, China, India, and Mexico.

Table 1: Variable Description

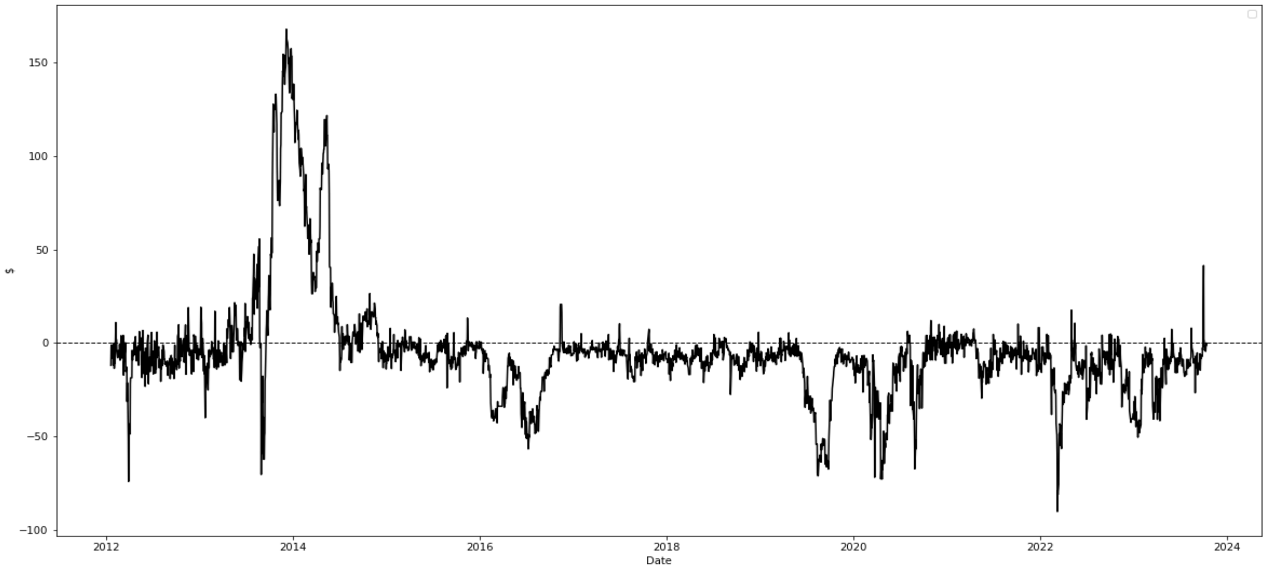
Metal	Country	Source	DataStream
	UK	ICE Benchmark Administration Ltd.	(Thomson Reuter)
	Australia	Perth Mint	(Thomson Reuter)
	Switzerland	UBS	(Thomson Reuter)
Gold	Japan	Tokyo Commodity Exchange	(Thomson Reuter)
	China	Shanghai Gold Exchange	(Thomson Reuter)
	India	Multi Commodity Exchange India	(Thomson Reuter)
	Mexico	Ideas Productivas en Comunicacion SC	(Thomson Reuter)
	UK	ICE Benchmark Administration Ltd.	(Thomson Reuter)
	Australia	Perth Mint	(Thomson Reuter)
Silver	Switzerland	UBS	(Thomson Reuter)
	USA	Thomson Reuters	(Thomson Reuter)
	China	Shanghai Gold Exchange	(Thomson Reuter)
	India	Multi Commodity Exchange India	(Thomson Reuter)
	UK	London Metal Exchange	(Thomson Reuter)
Platinum	Australia	Perth Mint	(Thomson Reuter)
	China	Shanghai Gold Exchange	(Thomson Reuter)
	Hongkong	Johnson Matthey	(Thomson Reuter)
Palladium	USA	London Metal Exchange	(Thomson Reuter)
	Australia	Perth Mint	(Thomson Reuter)

We use the sample data comprised of daily closing spot prices and their log returns for four precious metals - gold, silver, platinum, and palladium. Our sample data covers 9 developed and emerging economies. All daily prices of four precious metals are quoted in the respective local currencies. The pricing data series spans over 50 years, ranging from the most extended period for the UK from 1968 to the shortest period for Australia from 2008. The data for all four precious metals is gathered from Thomson Reuters Financial DataStream, as shown in Table 1. Furthermore, the period covering gold and silver data starts from 1968, platinum data begins from 1976, and palladium starts from 1987.

This data, however, is not homogeneous, even within metals, and these markets have significant differences.

For gold, the UK price is based on the London Bullion Market Association (LBMA) Auction, which is seen as the global benchmark price for gold and is denominated in US Dollars. In contrast, the Chinese price comes from an exchange in a country where import and export controls are imposed on gold, which often results in significant deviations between the prices. The price divergence from 2012 is shown in Figure 1 below.

Figure 1: London – Shanghai Discount/Premium (US$)



Similarly, for Palladium, the Australian price comes from a mint where bars and coins are made and sold, whereas the US Dollar price comes from the London Metal Exchange, where a new future is issued each day with a new delivery date.

Table 2: Descriptive Statistics for Precious Metals Returns

Metals	Country	Mean	Median	SD	Maximum	Minimum	Skewness	Kurtosis
	UK	0.001	0.000	0.219	4.102	-3.898	0.837	48.402
	Australia	0.002	0.003	0.154	1.912	-1.787	0.162	25.056
	Switzerland	0.001	0.000	0.204	3.901	-2.916	0.346	44.511
Gold	Japan	0.001	0.005	0.136	1.517	-1.149	-0.408	19.136
	China	0.004	0.000	0.205	2.118	-1.822	-0.219	13.570
	India	0.003	0.000	0.068	0.790	-0.566	0.055	15.886
	Mexico	0.001	0.000	0.150	8.508	-8.508	-0.008	32.104
	UK	0.012	0.000	0.021	0.412	-0.409	0.013	38.898
	Australia	0.012	0.000	0.926	23.380	-19.200	1.067	69.703
	Switzerland	0.000	0.000	0.298	2.065	-3.721	-0.949	14.086
Silver	USA	0.008	0.000	0.851	5.899	-10.138	-0.526	10.979
	China	0.000	0.000	0.189	1.023	-1.288	-0.498	10.189
	India	0.003	0.000	0.151	1.148	-1.470	-0.546	13.569
	UK	0.003	0.000	0.252	2.442	-2.415	-0.289	12.312
Platinum	Australia	0.002	0.001	0.181	1.671	-1.631	-0.012	10.958
	China	0.000	0.000	0.225	1.752	-2.852	-0.693	15.465
	Hongkong	0.002	0.000	0.202	2.409	-2.049	0.014	13.460
Palladium	USA	0.000	0.000	0.019	0.158	-0.179	-0.175	16614.000
	Australia	0.004	0.000	0.025	0.685	-0.682	0.355	238.743

Notes: *The mean values are based on the log returns of daily prices for four precious metals.*

5 Empirical Analysis

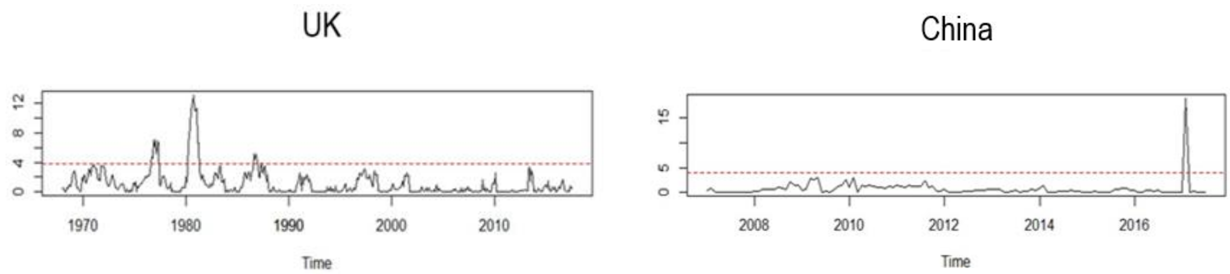
The macroeconomic environment, government policies, world events, and often changes in monetary policies inform the precious metals market volatility. It is validated from the test findings, as reported in Figure 2 – 13, the automatic portmanteau (AQ) of Escanciano and Lobato (2009) and automatic variance ratio (AVR) test of Kim (2009). We report the empirical results of the tests in section 5.1, 5.2 and 5.3 and provide analysis to determine whether precious metals markets are efficient (H_0) across developed and emerging markets.

5.1 Automatic portmanteau test (AQ)

We test the AQ statistic to calculate and evaluate the time-varying return predictability. The proposed test is desirable as the researcher does not need to specify the order of the autocorrelation measured, and the test chooses this number automatically. The asymptotic null distribution is chi-square with one degree of freedom, so there is no need to use a bootstrap method to estimate critical values. Furthermore, the test is robust for the existence of an unknown type of conditional heteroskedasticity. The AQ test is significant since it offers higher robustness in simulations than other current experiments, especially for models that have widely used in empirical finance, such as the spectral based test of Deo (2000) showing that the revised variant of the Cramér Von-Mises statistics has the normal restricting distribution that would be obtained without conditional heteroscedasticity. For further details of the test, readers are advised to see Escanciano and Lobato (2009) . We use a moving subsample window of 2 years daily data. The horizontal line shows a 5% asymptotic critical value of 3.84. Thus, if the AQ value is higher than the critical value, we reject the null hypothesis of having a martingale difference hypothesis (MDH).

Figure 2 depicts the AQ result for gold markets, indicating that gold markets are efficient throughout developed and emerging economies for the majority of the time. However, the gold market does deviate from market efficiency, such as in the 1980s in the UK, 2009 in Australia, and 2018 in China.

Figure 2: Gold AQ Test



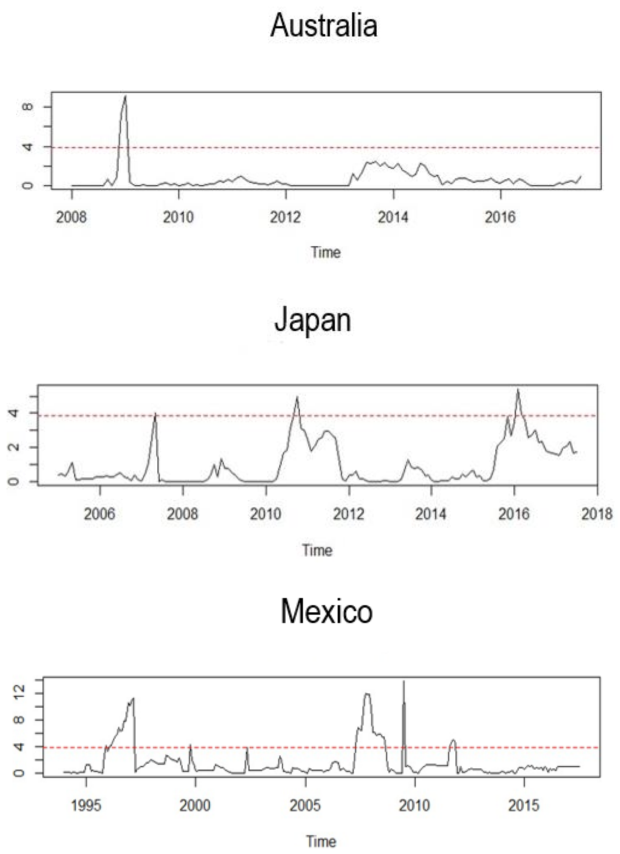
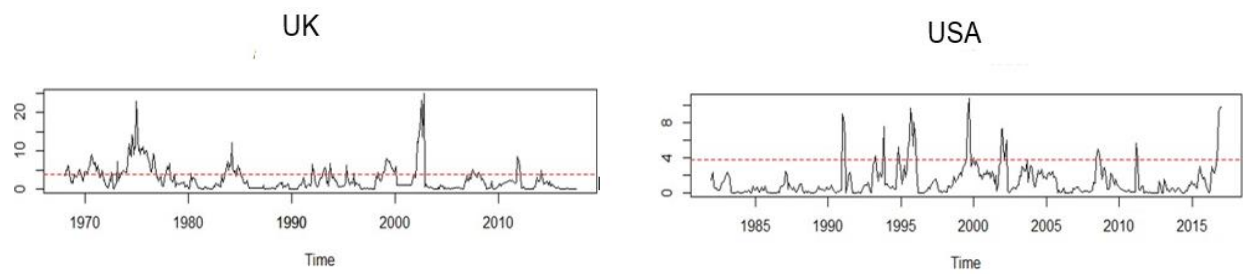


Figure 3 illustrates the AQ result for silver markets, demonstrating how silver markets perform differently in developed and emerging economies, with many more inefficient episodes seen in the developed markets below. The silver markets in developed economies exhibit variations in market efficiency during different time periods, which do not match the time periods for deviations from efficiency for gold markets in some domestic settings. Nevertheless, it is evident that the markets in emerging economies like China and India are highly efficient, though both show deviations in 2011 first in India and then in China.

Figure 3: Silver AQ Test



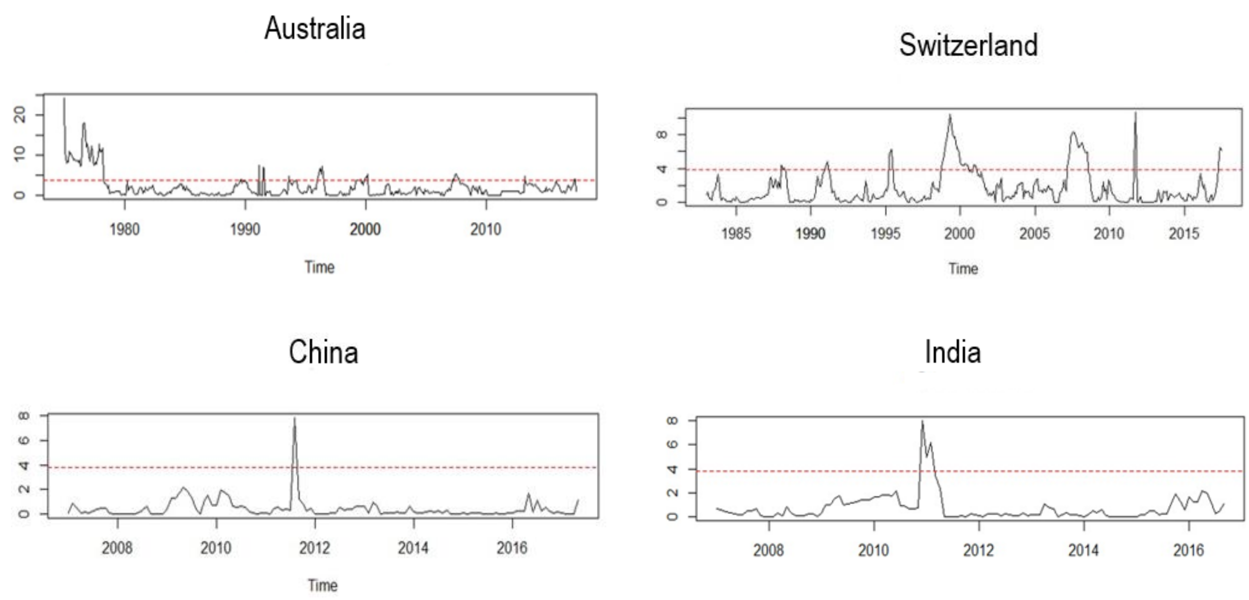


Figure 4: Platinum AQ Test

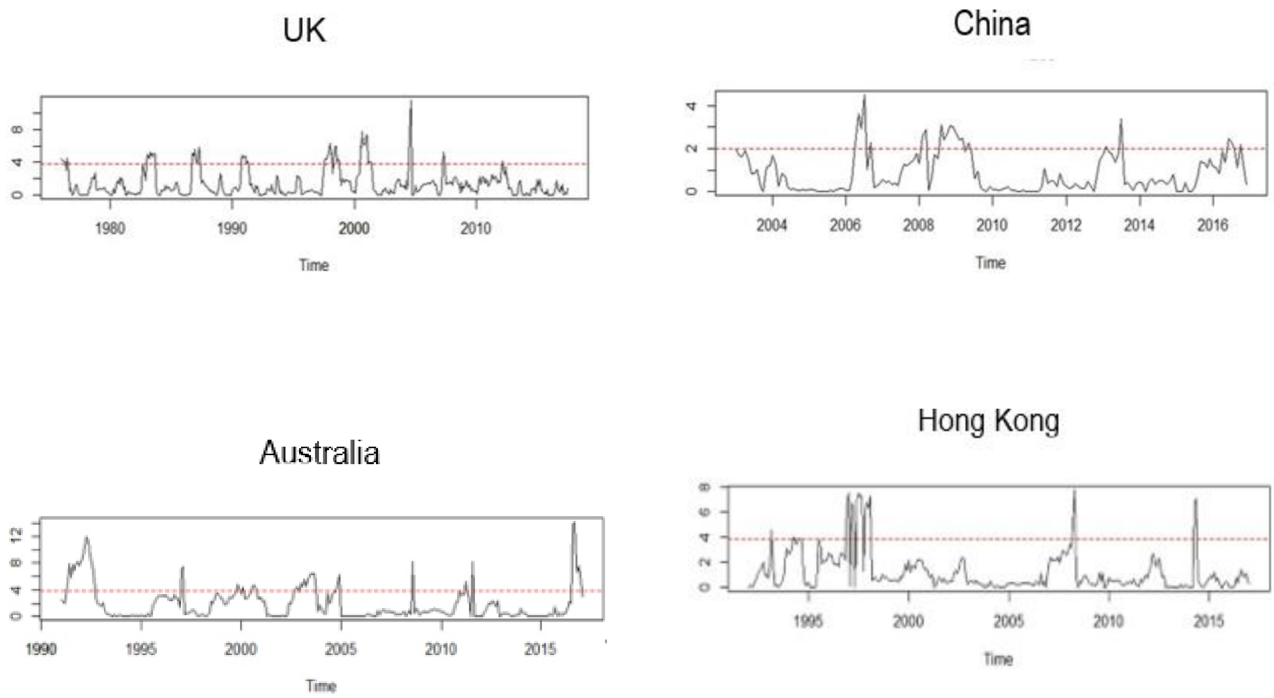
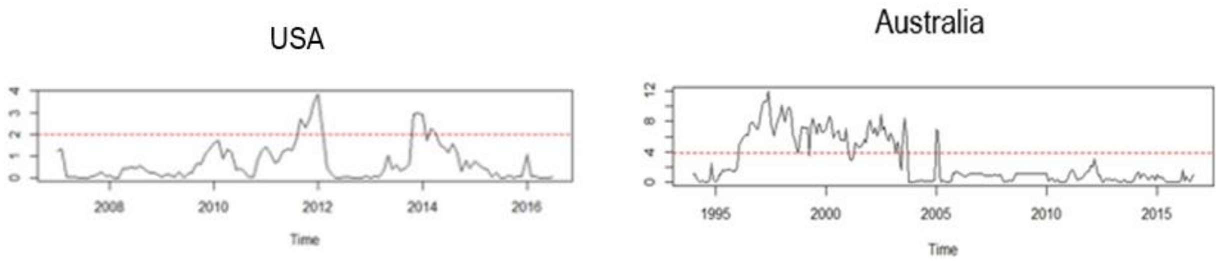


Figure 4 (above) and Figure 5 show the AQ result for Platinum and Palladium markets. Australian palladium markets have demonstrated consistent efficiency since 2006, making the palladium market less predictable following a long period of inefficient pre-2005. In contrast, the results for the same country for platinum show intermittent periods of inefficiency throughout the sample, while US palladium markets experienced two significant periods of inefficiency in 2011 and to a lesser extent in 2014. Once again, it is noteworthy that no pattern seems to exist either within metals or within domestic markets.

Figure 5: Palladium AQ Test



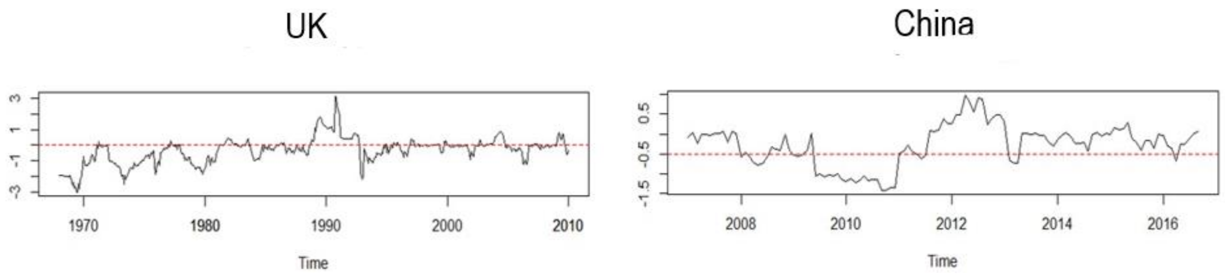
5.2 Automatic variance Ratio test (AVR)

The second method used is the Automatic Variance Ratio test (AVR) to measure the weak form of efficiency of metal markets and assess the predictability of metals returns. This method was initially suggested by Choi (1999) to determine the optimum value of k using an entirely data-dependent technique.

Figure 6 - 13 graphs display the version of AVR test wild bootstrap, the AVR statistics are reported in the null hypothesis along with 95 % confidence intervals. Therefore, If an AVR value is outside the confidence interval, MDH's null hypothesis (no return predictability) is rejected at the 5 % significance level, which is evidence that the market is weak-form inefficient. Furthermore, if the AVR value below 1 indicates the overall negative return autocorrelation and if the AVR value above 1, shows the overall positive return autocorrelation.

Figure 6 demonstrates the AVR result for gold markets, suggesting again that there is a lack of market efficiency in various time periods. The UK gold market tends to be quite efficient most of the time, except for a brief period in the late 1980s and 1990s. However, the gold markets in China, Australia, Switzerland, India, and Mexico have all shown a departure from market efficiency following the financial crisis in 2008.

Figure 6: Gold AVR Test



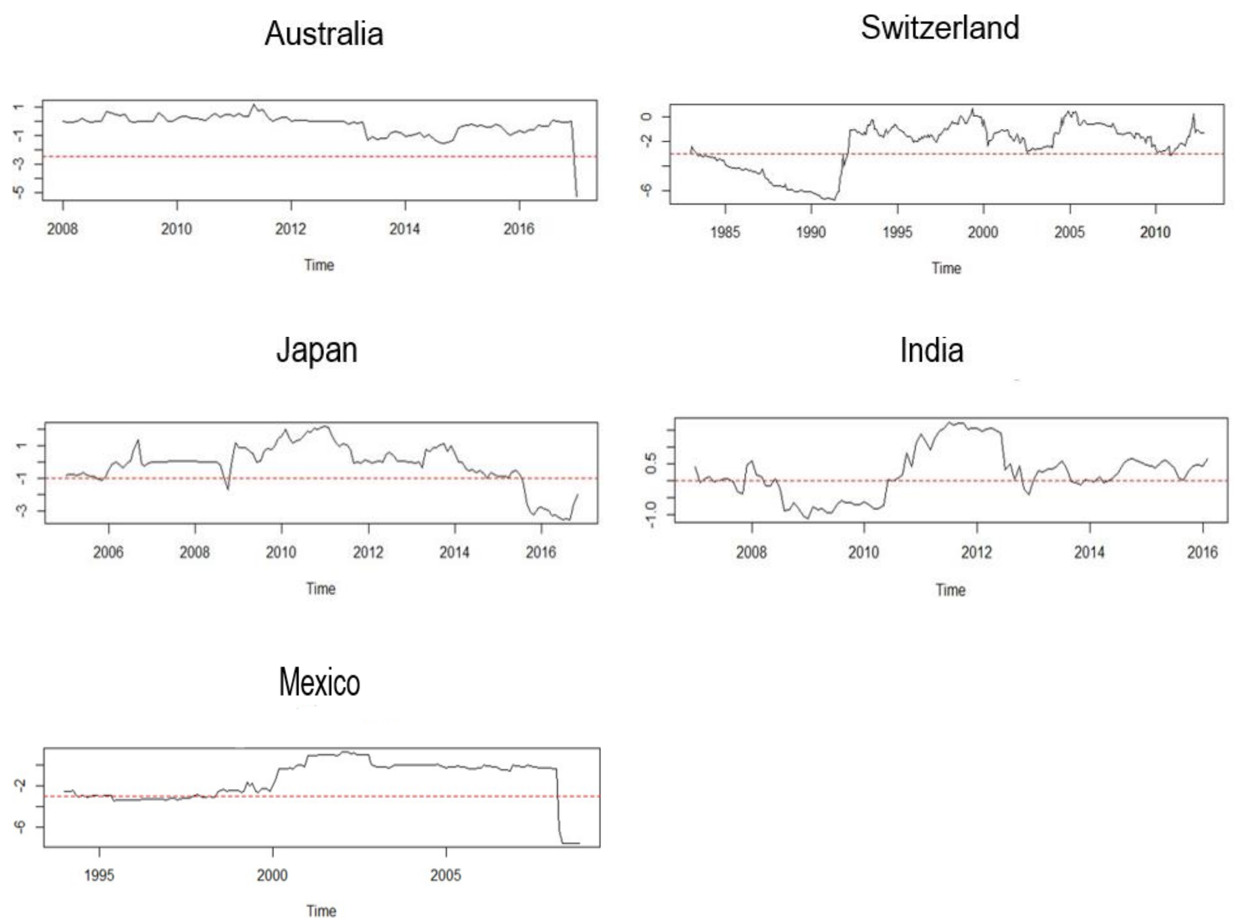


Figure 7 depicts the AVR outcome for silver markets, indicating that there are no concerns in the recent past in growing economies such as China and India, and that markets are unpredictable most of the time. However, developed economies show significant and frequent deviations from market efficiency over a long period of time, as in the Automatic Q Tests above.

Figure 7: Silver AVR Test

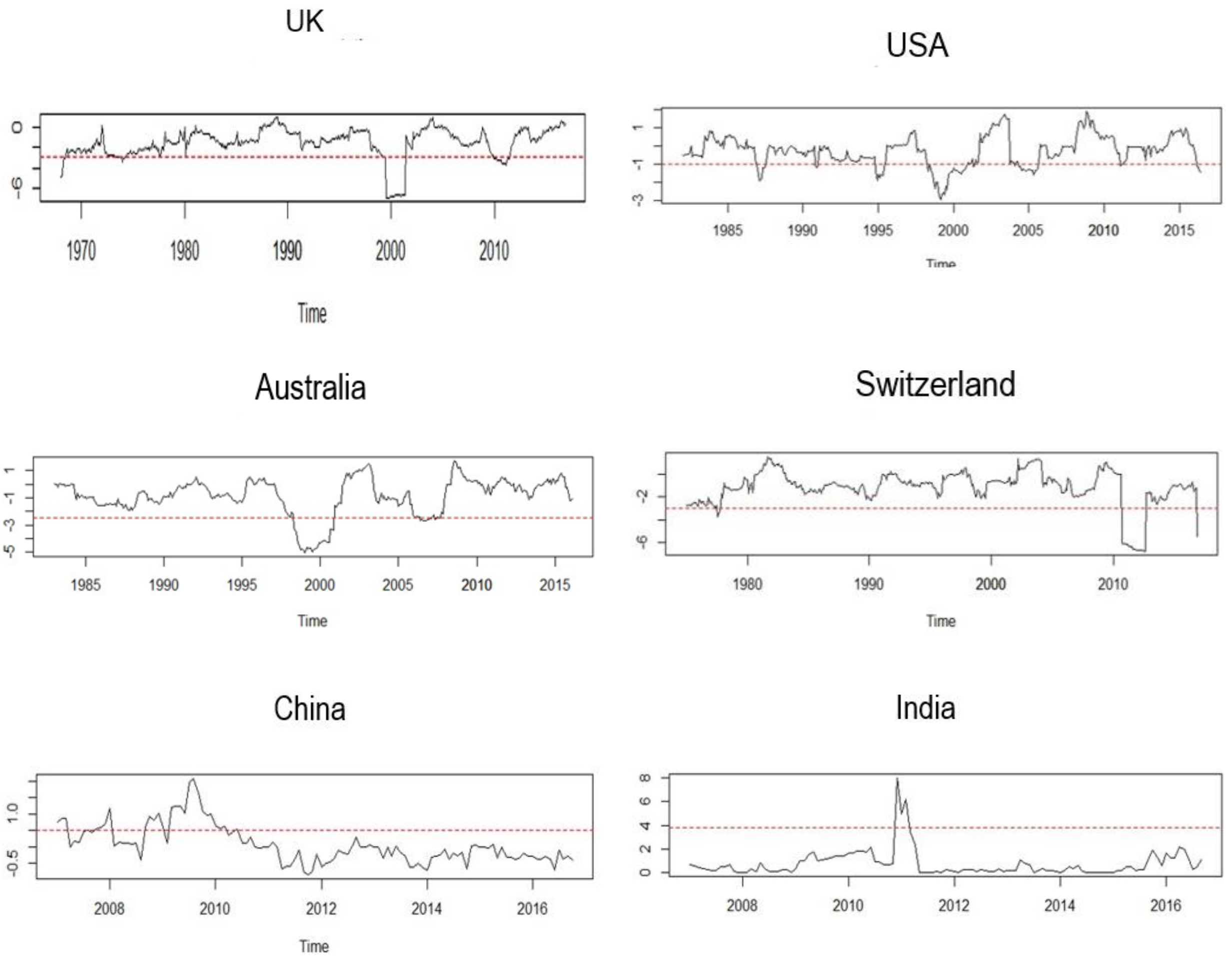
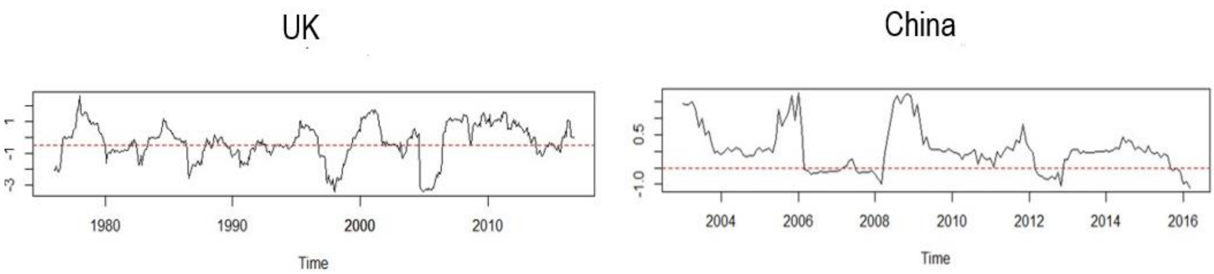
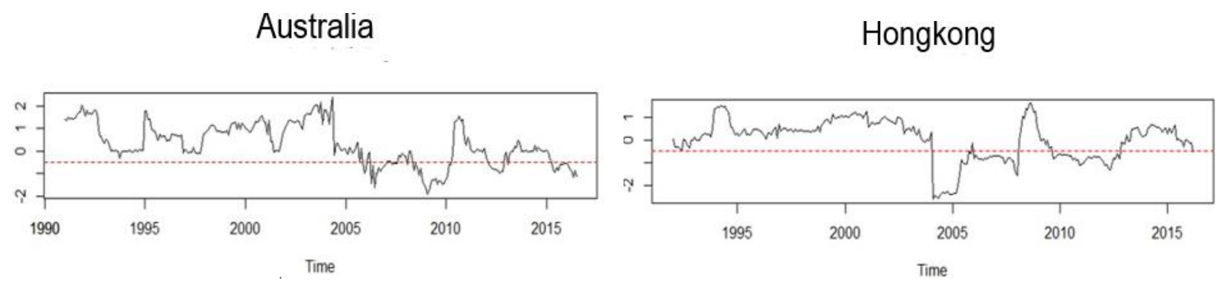


Figure 8: Platinum AVR Test





Figures 8 and 9 showcase the AVR result for platinum and palladium markets. Both metals show inefficiency in Australia from 1995 up to the mid-2000s – after that, however, Palladium is predominantly an efficient market while platinum continues to have prolonged periods of inefficiency. As these markets are much smaller and less liquid than gold and silver, it is not as surprising to see periods of inefficiency.

Figure 9: Palladium AVR Test

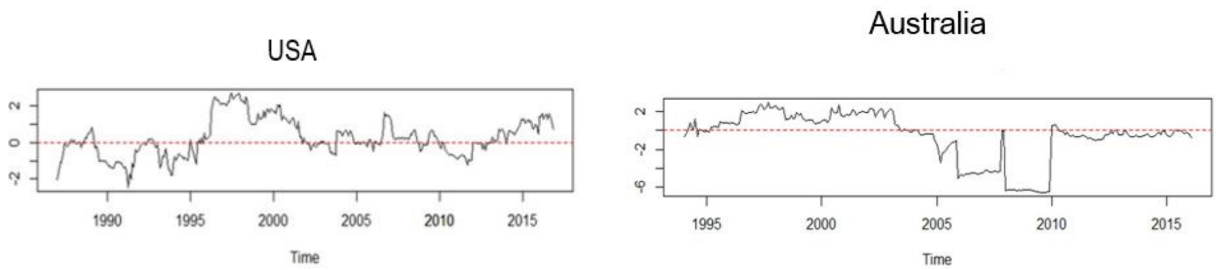
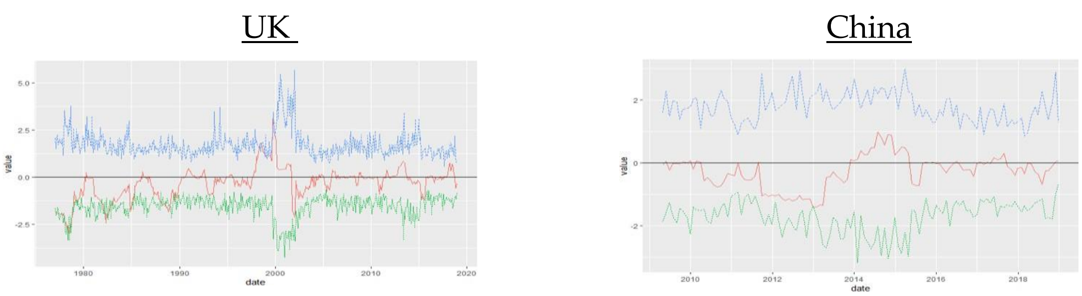
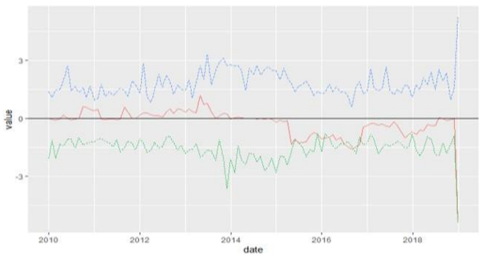


Figure 10 - 13 graphs display the version of AVR test wild bootstrap, the wild bootstrap is offered as a method for enhancing variance ratio test small sample features. In most circumstances, it is discovered that wild bootstrap tests have desirable size features and demonstrate higher power than their alternatives (Kim, 2006). The AVR statistics are reported in the null hypothesis along with 95 % confidence intervals. Therefore, if an AVR value is outside the confidence interval, MDH's null hypothesis (no return predictability) is rejected at the 5 % significance level, which is evidence that the market is weak-form inefficient. Furthermore, if the AVR value below 1 indicates the overall negative return autocorrelation and if the AVR value above 1, shows the overall positive return autocorrelation.

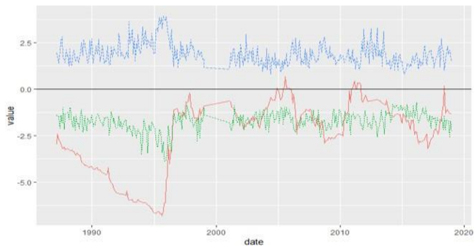
Figure 10: Gold Autoboot Variance Ratio Test



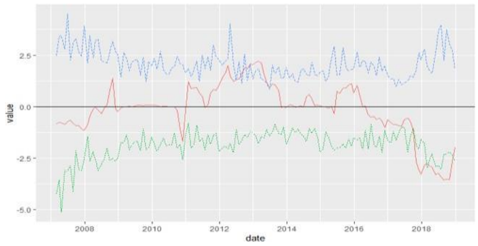
Australia



Switzerland



Japan



India

Mexico

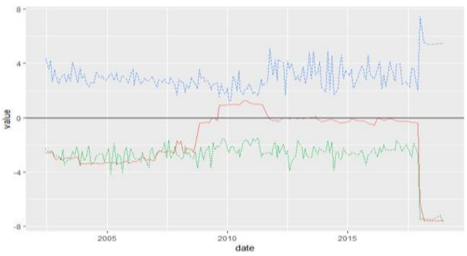
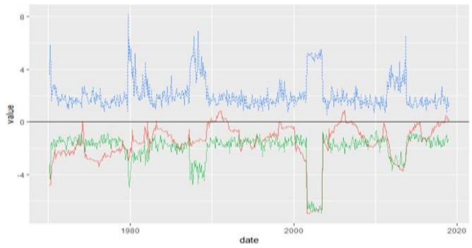
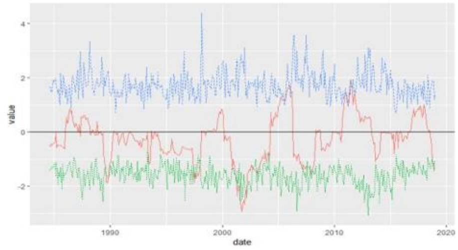


Figure 11: Silver Autoboot Variance Ratio Test

UK

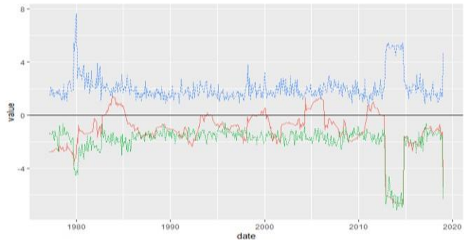


USA

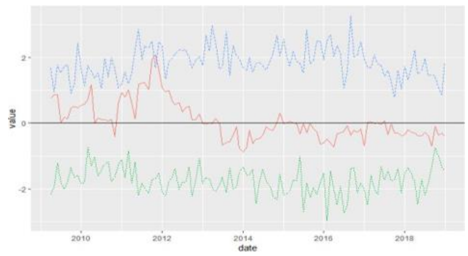


Switzerland

Australia



China



India

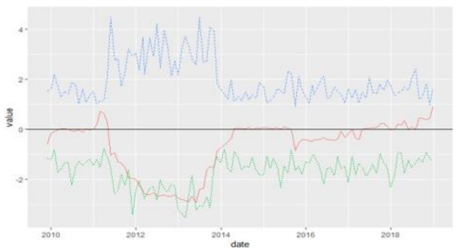
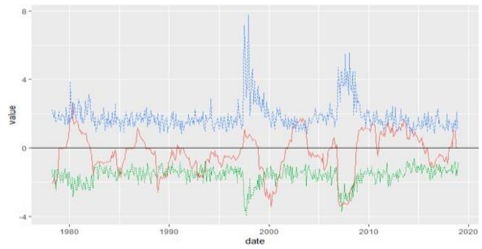
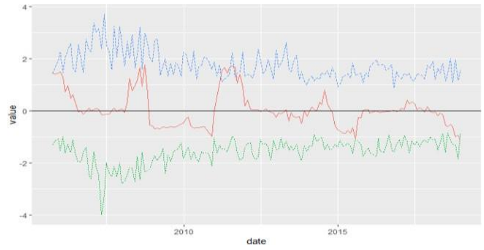


Figure 12: Platinum Autoboot Variance Ratio Test

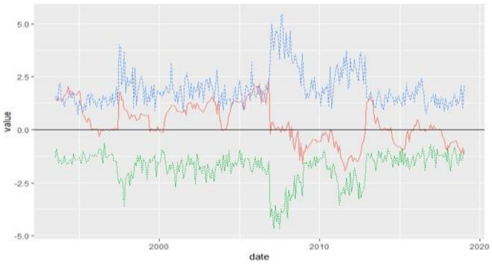
UK



China



Australia



Hongkong

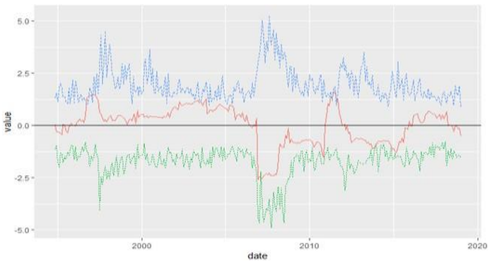
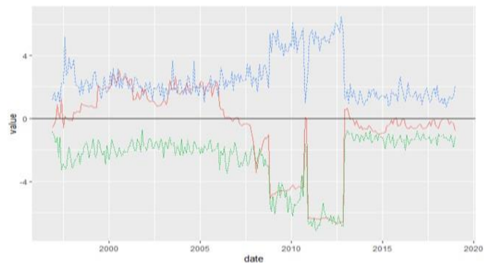


Figure 13: Palladium Autoboot Variance Ratio Test

USA

Australia



The overall results of AQ and AVR tests indicate that all precious metals have been predictable across developed and emerging markets for several periods, as shown in figures 2 - 13. This means that these domestic precious metal markets frequently display a departure from market efficiency from time to time that matches the implications of AMH. However, the gold market had a long period of no-return predictability across developed and emerging markets since 2000. For UK and Switzerland gold market, both tests AQ and AVR reject the MDH for 1982 and 2019, as shown in figures 2 and 6. The timing is in line with the USA's tight monetary policy of 1982, which led to deflation and high-interest rates. It also coincided with Reagan's action on joint interventions with major central banks that delayed dollar appreciation. Furthermore, for the Swiss market as the sub-sample window shifts for 1985 - 1992, AQ test rejects the gold

MDH, which coincides with tensions in South African gold mines, high US dollar rate in 1989, Iraq invasion of Kuwait and fears of inflation and higher interest rate expectation in the US in 1992 (Charles et al., 2015).

As for as Chinese gold market is concerned, there is a massive spike in 2011, 2012 and 2018 that shows the departure from market efficiency, as shown in figures 2, 3, 6 - 8 and 11. The Chinese economy was under pressure in 2018 by a continuous fall in investment and low consumption; the external environment is disturbed by the Sino-US trade war and slow economic growth in Europe. The monetary policy trend was also adjusted, and monetary policy shifted from neutral to moderately neutral. Moreover, a series of tax incentives were issued to stimulate private investment by the end of 2018 (Cheng, 2019). Likewise, a disturbance occurs in Australia's gold market in 2009, Mexico, and India's gold market, as seen in Figures 1, 2, 6 and 10. The Global Financial Crisis (GFC) followed by the global economy's worst contraction since World War II. During this time, developed economies (Australia) and emerging economies (Mexico and India) performed better than other developed economies on nearly all relevant indicators. However, there was stress on the financial conditions, but the financial system remained remarkably well maintained by the Australian government; the economy was slowing down, but not down in recession; while unemployment grew, it did much less than in many other advanced economies. Furthermore, the Fair Work Act 2009 was implemented with the provisions, and a full fair work package was operationalized by the Rudd Government from 1 January 2010 on, following the opening of the national employment standards (NES) and the modern awards (Cooper, 2010).

Silver, platinum, and palladium markets have become the most efficient since 2005 across developed and emerging markets. The AQ and AVR tests reject the MDH on the developed markets mainly in the UK and Australia in the period 1978–1979 as seen in figures 2 - 10 which can be clarified by the silver exploitation triggered by the Hunt brothers in cornering the silver market (Schacter, 1986). The rejection of the MDH by the AQ and AVR tests in the UK silver market at the end of 1984 coincides with the launch of the Commodity Exchange silver options market in October 1984, in which traders could swap options on Comex's silver futures at rates decided by an ongoing rise and not by the dealer fiat. Furthermore, the AQ and AVR results started heading to the rejection zone in late 1992, showing a significant deviation in market efficiency in the US silver market (Charles et al., 2015). The Kuwait occupation by Iraq in August 1990 and the Desert Storm operation in January 1991 led to the departure from market efficiency for silver. Moreover, the demand for jewelry, photography, and electronics, together with the increase in supplies from Mexico and Peru, maybe strictly linked to the UK and Swiss silver market's rejection of MDH in the early 2000s. (Howell et al., 1992).

The AQ and AVR test results for platinum and palladium often reject the MDH, and these metals markets have become more efficient from 2005, as shown in figure 5, 6, 9 and 10. Our results validate the findings of Ismail et al., (2013), report that during the global financial crisis, these two metals (Platinum and Palladium) were resilient, and investment in them was less risky than in other metals markets (Gold and Silver). The AQ and AVR tests reject the MDH for UK Platinum and Palladium markets from mid-2002 with increasing automotive, industrial demand, and production problems due to fear of strikes in Russian and South African producers. Moreover, these tests started heading to the rejection area in the early 2000s because of market crashes such as the bursting of the dot-com bubble of 2001, a subprime bubble in the mid-2000s, and geopolitical events such as Iraq war in 2003 (Uddin et al., 2018).

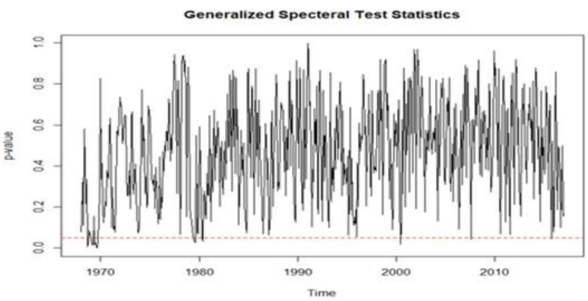
5.3 Generalised Spectral Test (GS)

We also use the generalized spectral test (GS) to test the weak-form efficiency in precious metals across developed and emerging markets. As stated earlier, in section 2.4, the AQ and AVR tests are based on autocorrelation, which can only detect linear dependence. Therefore, Escanciano and Velasco (2006) proposed a generalized spectral test (GS) to capture both linear and nonlinear dependence properties of a sample. Besides, they also include the wild bootstrapping similarly, as we described earlier in the AVR test. Thus, if the p-value is less than 0.05, the hypothesis of no (linear and nonlinear) return predictability is rejected at the 5 %level of significance. In other words, if the p-value is less than 0.05, then it means that the test is significant and a violation of the EMH has occurred.

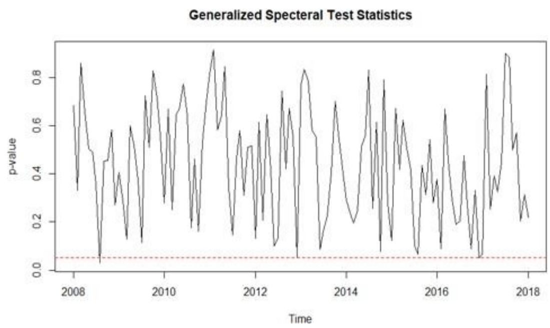
Figures 14 - 17 display the p-values for the GS test for daily data. The linear AVR and AQ tests findings as stated above that the null of no predictability is rejected at the 5% level of significance before 1980. The outcomes of the GS test are broadly compatible with the AVR and AQ result, which clearly shows that nonlinear dependence has not been a strong feature across developed and emerging markets.

Figure 14: Gold Generalized Spectral Test

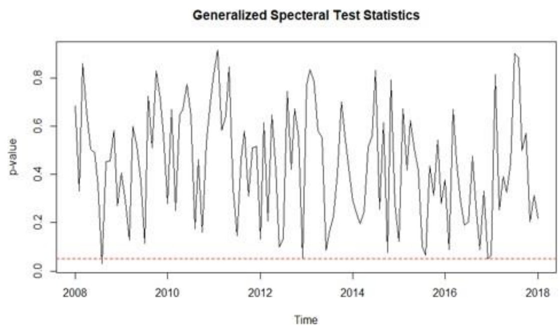
UK



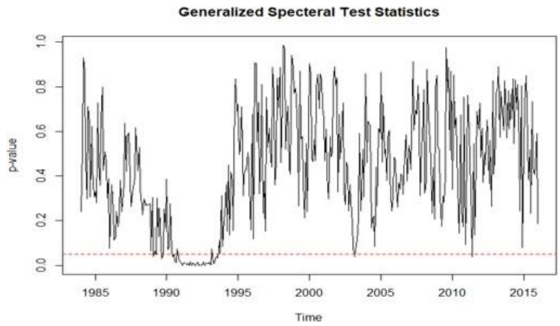
China



Australia

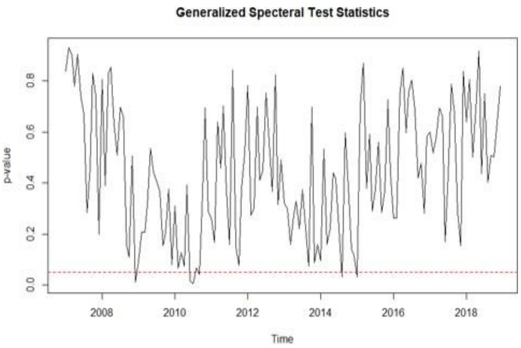


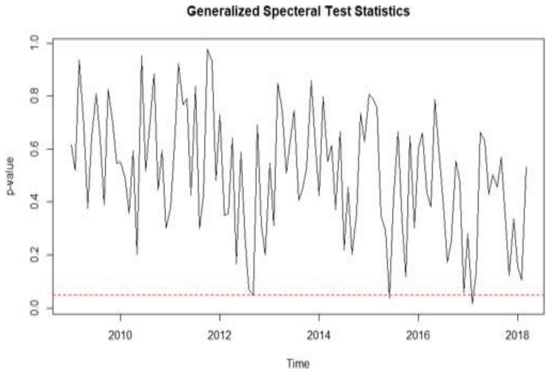
Switzerland



Japan

India





Mexico

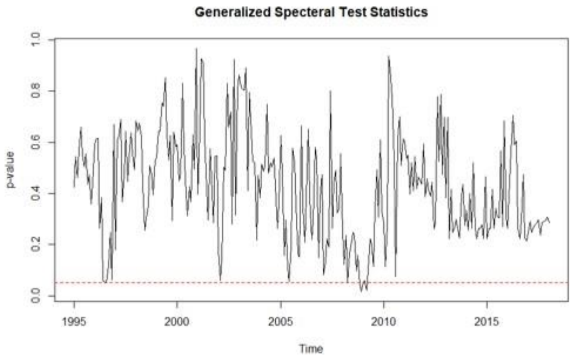
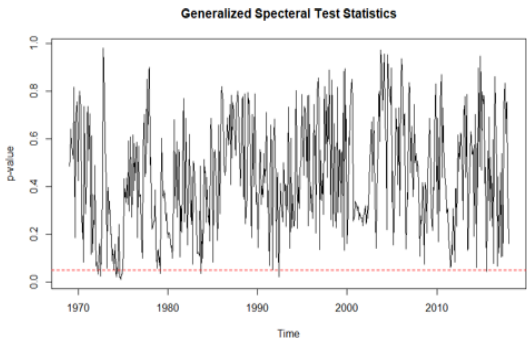
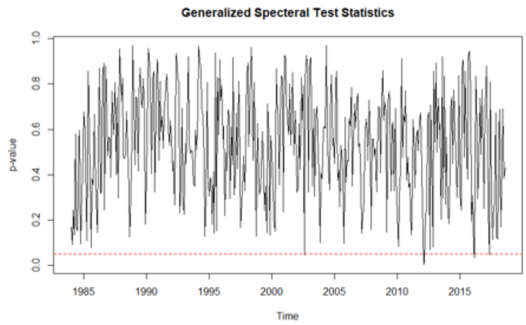


Figure 15: Silver Generalized Spectral Test

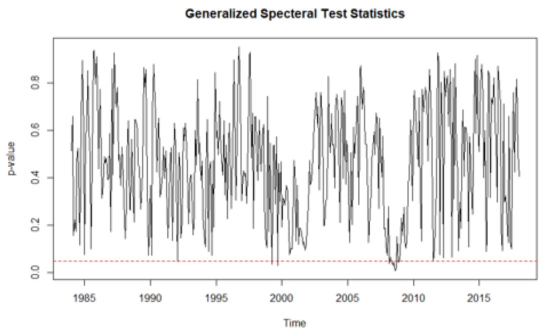
UK



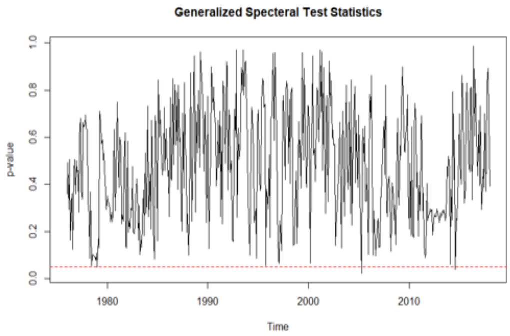
USA



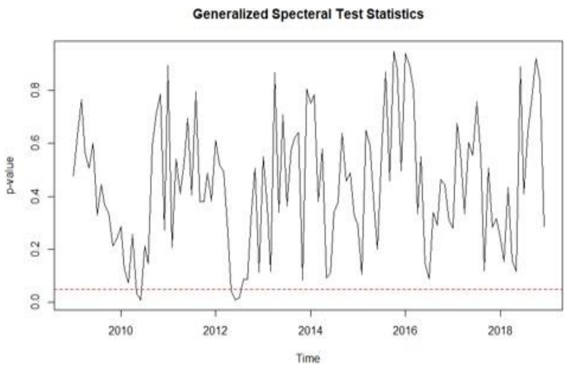
Switzerland



Australia



China



India

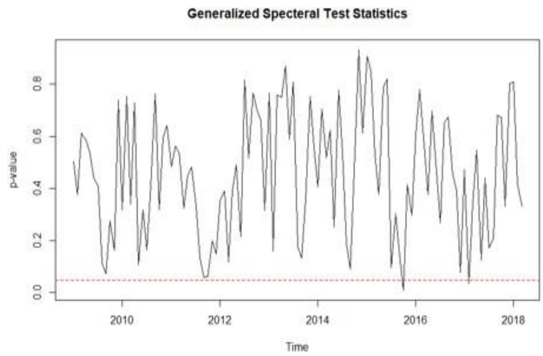
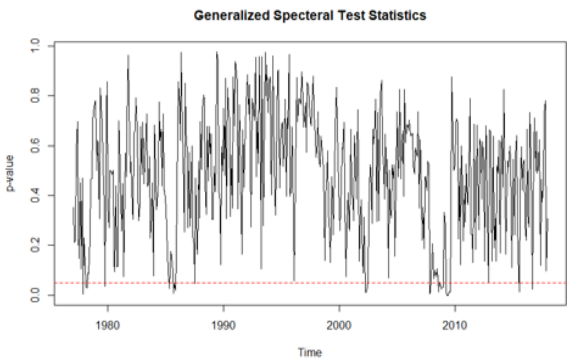
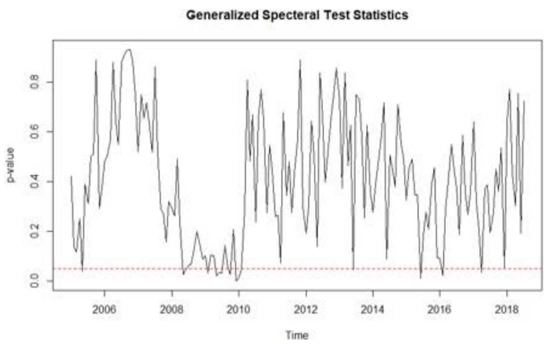


Figure 16: Platinum Generalized Spectral Test

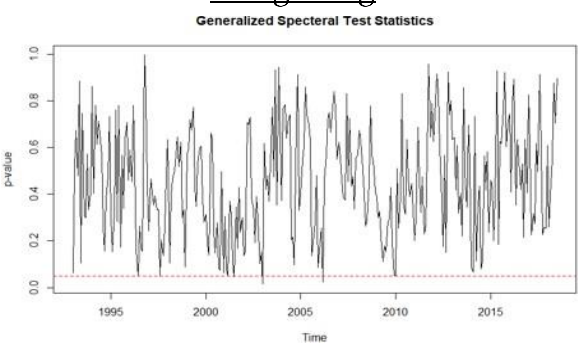
UK



China



Hong Kong



Australia

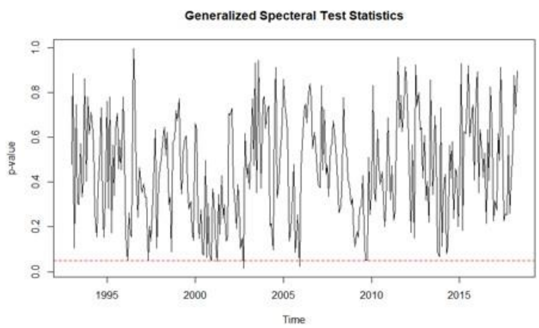
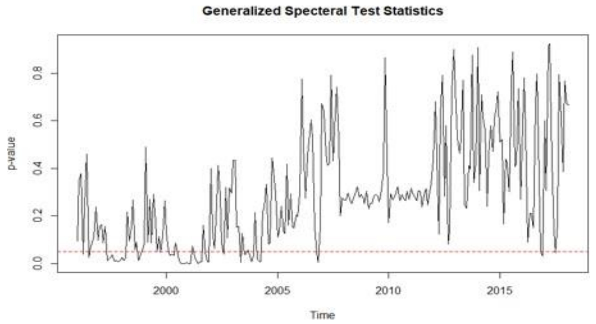
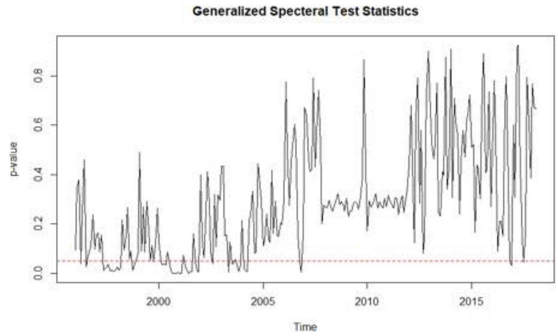


Figure 17: Palladium Generalized Spectral Test

USA



Australia



6 Conclusion

Precious metals can form a core component of an investment portfolio, as these assets act as a diversifier and safe haven for investors and institutions. Whether these commodities conform to the Efficient markets hypothesis when traded in domestic currencies around the world is a question that should be addressed to these investors. This paper examines the weak-form efficiency of the four precious metals (gold, silver, platinum, and palladium) across developed and emerging markets.

To analyze this, we employ recently developed tests that build upon the standard tests of market efficiency found in the literature over the last 50 years. The traditional methods are Autocorrelation-based and Spectrum-based MDH experiments; here, we use updated versions of these: (i) the Automatic Portmanteau Test (AQ), (ii) the Automatic Variance Ratio Test (AVR), and (iii) the Generalized Spectral Test, used to identify potential nonlinear dependency in metals returns.

Our analysis indicates that the predictability for the domestic prices of the four metals markets differs throughout the sample periods examined. We find evidence that the precious metals markets frequently deviate from market efficiency, a finding that points to the Adaptative Markets Hypothesis as a better description of how these markets operate than the traditional Efficient Markets Hypothesis. Several factors may contribute to these periods of inefficiency, including technical market differences (such as Exchange versus OTC trading), economic heterogeneity among domestic markets (such as import/export controls), and speculative strategies employed by investors to exploit perceived or real market imperfections. The findings of this study suggest that market efficiency for four precious metals varies over time across developed and emerging markets and between the metals themselves.

The findings of this study have practical and social implications for individual investors and institutions when selecting precious metals for inclusion in their portfolios to diversify the various risks they face. Investors can leverage the dynamic information available to mitigate investment risks at various domestic metal exchanges. Moreover, this study provides valuable insights for individual and institutional investors, portfolio managers, and brokers to make informed price forecasts based on its findings. Therefore, it is imperative to examine the characteristics of each precious metal in each domestic market to be able to assess the benefit of their inclusion to hedge portfolio risk rather than accepting the results of studies on their properties in US Dollars – where most of the research has taken place to date.

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