The Macroeconomic Determinants and Market Efficiency of Precious Metals: An Empirical Evidence of International Markets

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by

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To my parents, who had motivated my curiosity

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Declaration

I declare that this thesis is my own work and has not been submitted to another university for a degree.

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Abstract

This empirical study extends market efficiency application to precious metals. Literature suggests that prices of four precious metals (i.e., Gold, Silver, Platinum, and Palladium) fluctuate due to instability of macroeconomic factors globally. Moreover, the impact of macroeconomic factors causes uncertainty in the prices of metals which affects the investors' return. To test the robustness of the precious metals price efficiency, this thesis is divided into three separate empirical studies that measure market efficiency and analyse the impact of macroeconomic factors on pricing in developed and emerging economies.

Chapter 2 (Paper 1) examines weak-form efficiency in the precious metal market using the Automatic Portmanteau, Automatic Variance Ratio, Autoboot Variance Ratio, and Generalized Spectral Shape tests. The findings demonstrate that market efficiency for four precious metals in developed and emerging economies changes over time. Market efficiency may vary due to technical changes, economic booms and busts. The other reason could be that markets are fragmented due to restrictions, lunar cycles, market complexity, and other challenges.

Chapter 3 (Paper 2) investigates the relationship between macroeconomic factors and precious metals prices across developed and emerging markets from 1979 to 2020 using multiple time series techniques – Johansen Cointegration, VECM, VAR, ARDL model, and Wald tests. The findings revealed the long-run and short -run relationships between precious metals prices and macroeconomic factors vary depending on the country of the study. In the long run, cointegrating relationships are unstable and differ significantly between developed and emerging economies. The causality test results between four precious metals and major macroeconomic indicators vary depending on the country and the sample length of the frequency distributions used.

Chapter 4 (Paper 3) examined how macroeconomic factors collectively impact gold, silver, and platinum prices in developed and emerging economies using the panel data unit root test and dynamic panel data model. The findings demonstrate that macroeconomic factors affect precious metal prices in developed and emerging economies.

1. Chapter 1 Introduction to the Thesis

1.1 Introduction

This thesis is divided into three papers within the core field of finance. Paper 1 discusses the *Market Efficiency of Precious Metals*; *Evidence from developed and Emerging Economies* using the Automatic Portmanteau test, Automatic Variance Ratio test, Autoboot Variance ratio test and Generalized Spectral Shape test. Paper 2 examines the relationship between macroeconomic factors and precious metals prices across developed and emerging markets from 1979 to 2020, employing multiple time series techniques such as the Johansen cointegration test, the Vector Error Correction Model (VECM), the Vector Autoregression Model (VAR), the Autoregressive Distributed Lag (ARDL) model, and the Wald test. Paper 3 analyses the combined effect of *Macroeconomic determinants of Precious Metals Prices: Panel data Evidence* across developed and emerging markets through employing the unit root test and dynamic panel data model to investigate relationship nature.

Metals are necessary for human life. Our civilization is predicated in great part on our ability to mine and process metals. Furthermore, humans have used metals for their survival, to store the value of money, and to use in industrial processes. In fact, the usage of metals has been associated with specific times in human history, such as the Stone Age (before metals), the Bronze Age, and the Iron Age, among others. Metals are regarded valuable and are used as ornamentation, but others are deemed valuable and have been used as a store of value and as money to enable the trade of products in the past (Aggarwal et al., 2016). Metals have always been and will continue to be a significant part of our economy and society. As a result, it is critical to understand how metals are valued and exchanged in the marketplace. Moreover, metals trading is crucial since they represent attributes with a wide range of industrial applications and separate and significant asset classes for investors. Due to the fact that metals prices and volatility do not all move in the same direction at the same time, they offer the opportunity for risk diversification (Batten et al., 2010).

Financially driven business cycles are partially due to commodities price volatility. Business cycles tend to occur more frequently, every decade whereas financial business cycles tend to occur over longer duration, referred to as super cycle (Erten and Ocampo, 2013). Metal prices, although commodities but are observed to display of cycle patterns 20–70 years which are longer than a decade but are associated with business cycles. These longer-term price cycles are not only long in duration, but they also appear to impact several metal prices simultaneously, that suggest precious metals prices are impacted by financial as well as business factors leading to their designation as supercycles; three such long cycles have been reported in the last 150 years (Cuddington and Zellou, 2013). Roberts (2009) reported that metals prices cycles are longer and deeper than the business cycle. As a result, metals prices, like other commodities, are thought to have co-movements greater than the fundamentals (Pindyck and Rotemberg, 1988). However, there is evidence that the excess co-movement of metals prices is relatively small, owing primarily to inventory shocks after accounting for supply and demand impacts (Lescaroux, 2009). The real price of metals declined by 0.2 percent per year in absolute terms and climbed by 2.2 percent per year in nominal terms over the twentieth century. However, there was a noticeable difference between the different metals. Moreover, prices have been driven mostly by technological advancements, the discovery of new and low-cost deposit locations, and fluctuations in consumer demand during the previous hundred years. On the other hand, prices of metals have climbed by an average of 8 percent per year since 2000 – measured in nominal terms (Aggarwal et al., 2016).

Gold experienced the largest rise in prices among the major metals; this may be attributed to investor expectations of gold being a safe asset class during the financial crisis. Furthermore, the rise may be explained by rising production costs and limited new high-grade deposit discoveries. Many analysts have also reported rising demand for gold from developing countries such as India and China as a contributing factor to the price increase in gold. However, the McKinsey Basic Materials Institute reported that the demand from emerging countries had been a major contributing factor; shifting supply costs due to geological difficulties and input cost increases (especially energy) have also been important factors behind rising prices (Dobbs et al., 2013). The modes of variation in the prices of gold and silver are very different from those in the prices of other metals. When it comes to price changes in gold and silver, there is a significant non-normality and non-stationarity in the distributions of the changes and significant skewness and kurtosis is observed in the mean and variance (Aggarwal and Sundararaghavan, 1987; Aggarwal and Soenen, 1988).

Aggarwal and Sundararaghavan (1987) studied silver futures prices. Aggarwal and Sundararaghavan found significant and persistent dependence between the two prices, which can be used to generate excess risk-adjusted returns with mechanical filter trading algorithms. These significant variations in the means and variances are observed near round number gold prices, indicating the presence of psychological obstacles (Lucey et al., 2006). These are key indicators of gold and silver prices deviating from market efficiency.

This thesis consists of six chapters in total. Chapter 1 provides an overview of the entire thesis, the motivation for studying precious metals and summaries the background of the entire thesis. Chapters 2, 3, and 4 describe paper 1, 2, and 3. Finally, chapter 5 summaries the research's significant findings and gives recommendations for further research.

Paper 1 examines the market efficiency of four precious metals – gold, silver, platinum, and palladium, in precious metal markets and investigates whether precious metals markets are weak-form efficient across developed, emerging, and frontier markets. The market will be efficient when all the relevant information is reflected in prices. Moreover, the market can be weak, semi-strong, and strong for efficient (Fama, 2021). A weak form of EMH which is the lowest form of efficiency in which the current prices fully reflect all the information contained in historical financial asset prices; while investing in financial assets; the investors cannot get abnormal profits from other investors using the historical prices (Humphreys 1987). In a semi-strong efficient market, stock prices reflect all publicly accessible information about the firm's economic fundamentals. In strong form, the most efficient form of market efficiency where prices incorporate all public and private information; in this form of market efficiency no individual or institutional investors can predict the share prices, hence everyone has same set of information to make investment decision. The three forms of efficiencies are applicable in the case of precious metals. The precious daily spot pricing of precious metals has same characteristics as the stock market, hence we have used market efficiency theory to evaluate market efficiency for precious metals. Therefore, we have extracted the data from various data sources to test the seasonal or conditional effect in the metal markets which impact macroeconomic environment.

Paper 2 outlines the relationship between macroeconomic factors and precious metals prices across developed and emerging markets from 1979 to June 2020 using the multiple time series techniques – Johansen cointegration test, VECM, VAR, ARDL model, and Wald test. 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.

Paper 3 studies the combined effect of macroeconomic factors on the pricing of precious metals in developed and emerging economies. In this study, we use the panel data unit root test and dynamic panel data model to investigate relationship nature. The data set used here covers 1979–2020 for five developed and emerging economies: the United States of America, the United Kingdom, Japan, China, and India.

1.2 Motivation towards precious metals

The importance of precious metals has been around for centuries especially gold, and the Incas (the largest empire in pre-Columbian America), even it has been referred to as the tears of the sun (Lechtman, 1984). There is a mention of gold in the ancient Greek literature (Kurke, 1999) that suggest the significance of gold for as a mean of executing financial transactions. It is suggested that the first incidents of gold coin being used in around 700 BC, mainly in the Mediterranean and Middle East regions (Coldstream, 2004). This evidence the importance of precious metals as they had intrinsic value for humans. The four most important precious metals that dominate metal sector are gold, silver, platinum, and palladium, demonstrating their durability as some continue to fulfil some functions even today, thousands of years after their first use, though their usage has evolved over time. This is the rational for selecting these precious metals for this study.

In addition, to conduct the transaction, the precious metals gained importance as they were also used as an asset for the portfolio selection to diversify risk. The stable values of precious metals compliment financial investments such as stocks and bonds. The precious metals, in addition to their historical significance, they also possess unique characteristics such as the capacity to hedge against inflation and economic downturns (Hammoudeh et al., 2010). Amongst the four metals used in the study investors have a preference to invest their money into gold and silver, rather than other precious metals. This preference could be attributed to consumers sentiments and belief that these metals have greatest stability. During economic downturns, investment in gold and silver are believed to be less volatile as evidenced from the literature (Arouri et al., 2012).

The contemporary financial innovations have extended the use of precious metals within the futures, options, exchange-traded funds (ETFs). The use of precious metals within ETFs can affect precious metals volatility in price. Furthermore, precious metals are used as inputs for manufacturing, fluctuations in demand for products which used gold impacts on the prices of precious metals. For instance, during financial crisis 2007-2008, ETFs investment were significantly impacted as their demand increased due to financial markets volatility (Batten et al., 2010). This suggest investment decisions in precious metals are due to the risk mitigation capabilities of such metals, primarily when used with stocks and bonds in a portfolio (Chan and Young, 2006). The post ETF introduction, it became easier for retail investors to invest in the precious metals market that enabled investors to combine financial and ETFs investments. During the Brexit, the UK investors increased ETFs in their portfolio as gold ETFs volume rose to 2,000 metric tons for the first time since June 2013 (Corbet et al., 2020).

The other motivation for choosing precious metals for the study is the increased use of precious metals within the innovative technologies. Precious metals are extensively used within the high-value products such as electronics, solar energy, medicine, automobile and jewelry industry. There is an upward trend for the green technologies across the world as a means of mitigating human impact on the environment. Precious metals also play a vital role in computing technologies and particularly in cleaning the emissions that exit the tailpipe of gas and diesel vehicles (Sharaf, 2013). This suggest investment in precious metals is linked to environmental issues as well as innovations, though the use of precious metals in innovative technologies varies across the globe (Singh and Kumar, 2017).

There are many precious metals in the metal market. However, there are four leading precious metals namely - gold, silver, platinum, and palladium. These metals account for significant market share of precious metals as evidenced from the trade in ETFs. Therefore, on this basis and evidence from the literature, it was decided to exclusively focus on the four precious metals for this study.

The other reason for excluding the other precious metals such as rhodium, ruthenium and Iridium is that their traded volume on the leading stock exchanges such as Tokyo and New York stock exchange have thin trading and they are prone to "paper speculation." A small amount of trading, a few kilos of these metals, can cause a large variation in price. Hence, these metals are not traded on any stock markets, thus there is no opportunity to hedge against price fluctuations in its value (Hageluken, 2006). The other rational for selecting only these four precious metals is that only these metals are traded on the London Bullion Market Association. Most specifically, there is a limited use of rhodium or iridium in production and their trade volume is extremely low (Corti, 2005). Hence, the rational for focusing on four precious metals is aligned with the literature for this study.

Gold is a major reserve asset held by the central banks worldwide. According to the World Gold Council, the United States, Germany, France, and Italy kept around half of their capital reserves in gold bullion as of March 2004. Moreover, in times of economic and political instability, investors frequently take short-term speculative positions in gold and silver to protect themselves against market dangers (Hillier et al., 2006). Gold and silver are the metals that are more commonly used in the jewellery industry, and most of the time, investors take them as investment assets, especially in the extreme condition of the stock market's volatility (Apergis et al., 2014). Silver demand is primarily driven by industrial requirements (which account for around 40% of annual silver production) and jewellery (approximately 45 percent of annual silver production). Unlike gold, silver is not highly demanded by private investors. Only about 11% of total silver demand is attributable to financial investment (Radetzki, 1989).

A private investor's demand for gold manifests itself in two ways: through physical hoarding of gold bars and through investment in financial gold securities such as options, forward contracts, and warrants. The total amount of gold held by private individuals is not known, though it has been estimated to be approximately 22,000 tonnes globally (Sherman, 1986), comparable to the total amount held by governments. In most cases, silver is a byproduct of gold mining; in fact, gold mining accounts for as much as two-thirds of the world's total silver supply. This has resulted in a high correlation between the price of silver and that of gold.

Silver is one of the oldest financial assets due to its historical position as a currency. The benefits of using precious metals as currency were their scarcity, divisibility, and corrosion resistance. History demonstrated a few currencies used base metals, such as Byzantium, which was used as iron coins, but these were too heavy and rusted to be used as an effective currency (Averbury, 1903).

Over the last few decades, industrial metals have emerged as a viable alternative asset class that can be included in asset portfolio diversification. Global demand for industrial metals has increased rapidly since 2000, owing to the rapid urbanization and industrialization of emerging economies (e.g., China and India). The combination of rising demand and inelastic supply increased industrial metal prices (Figuerola-Ferretti et al., 2015), attracting many investors and resulting in the financialization of industrial metals (Cheng and Xiong, 2014). Watkins and McAleer (2008) also suggested that market participants other than manufacturing companies, such as banks, investment funds, and speculators, are becoming more interested in assets that track industrial metals performance. Supply and demand fundamentals are highly heterogeneous for precious metals. For example, investment demand for gold accounts for 36% of total demand, whereas demand for silver is primarily driven by industrial needs (40%) and jewelers (45%) (Hillier et al., 2006). Catalytic converters in automobiles increase demand for platinum and palladium by nearly 50%. Additionally, the four precious metals have a variety of sources, such as most gold is mined, officially sold, recycled, or written off as scrap. Similarly, silver is also mined from production, scrap recycling, disinvestment, and government sales (Tiwari et al., 2021).

Platinum and palladium concentrates are extremely rare in nature. A mixture of six platinoid elements is used in their production (Antonakakis and Kizys, 2015). (Steel, 1991) reported that the market for platinum metals used in automotive pollution control was expected to expand significantly, particularly for platinum and rhodium. To accommodate this growth, mining companies are investing in new mines and expanding existing ones to add additional Platinum Group Metals (PGM) capacity. There are six elements in the PGM: ruthenium, rhodium, palladium, osmium, iridium and platinum. Moreover, these metals are all extremely rare and occur in only a few concentrated deposits. Radetzki (1989) highlighted the distinct characteristics of each metal and examined the fundamental factors influencing price movements in the gold, silver, and platinum markets. He also reported that platinum mining is frequently associated with polymetallic ores and the majority of the platinum in mines is in the form of platinum ore. The platinum/palladium ratio in South African ores is approximately 1.4, with platinum entirely dominating mining economics. The ratio is just 0.25 in the ores explored by the USSR, implying that palladium is economically equivalent to platinum. Economic reasoning shows that the USSR's platinum supply is largely impacted by palladium market trends.

Platinum and palladium have recently been classified as precious metals. Platinum was initially regarded as a nuisance by Spanish gold prospectors while panning for gold in the 16th century, and palladium was discovered in 1802 by scientists working on improved platinum refining methods. While they are used as investments, their primary source of demand is industrial, such as catalytic converters' production for automobiles (McDonald and Hunt, 1982).

Platinum is also mined in conjunction with other metals (especially palladium and rhodium, ruthenium, nickel, and chrome). Platinum is mostly in demand from industry, which uses it to manufacture catalytic converters for automobiles. Private investment in platinum accounts for a modest portion of the world's supply; it accounts for less than 10% of the total amount demanded. Since central banks do not hold platinum in the form of reserves, the market for this metal is not immediately affected by changes in central banks' monetary policy (Hillier et al., 2006).

Many economists believe that gold is the leader in all precious metals, but silver has an edge over gold due to its industrial usage (Sari et al., 2010). While gold is considered the most valuable metal on the planet, platinum is considered the most valuable and rarest and has an industrial usage. An Olympic-sized pool depth would barely contain all the platinum ever mined if it were melted and poured into it. In contrast, gold would fill three pools in a single day (Welch and Compton, 2006). Lucey and Li (2015) also reported that gold is not a safe haven, although the others are; for instance, at the end of 1993 and 2007, both silver and palladium preserved their safe haven credentials, whilst gold experienced considerable price volatility.

The price of platinum usually, moves with other precious metals, particularly gold (Sari et al., 2010). However, palladium is inferior relative to platinum. Palladium is mostly used for catalytic converters in the automobile industry, which has increased the significance of palladium against other precious metals (Summers et al., 1988). Palladium also has extensive use within the dentistry and jewelry industry due to its naturally white properties. Moreover, it is also beneficial when alloyed with gold to produce "white gold," which is highly expensive in the jewelry industry. Moreover, palladium jewelry competes with platinum jewelry in China (Corti, 2005).

1.3 Background to the Thesis

This section provides a brief history of precious metals and discusses the ways in which the effects of macroeconomic factors on precious metals have been examined in previous research. This thesis investigates three distinct research questions that are interlinked to the field of finance and the topic of the thesis. In the first instance, we examine whether the precious metals markets are weak form efficient across developed and emerging economies. Secondly, this study investigates the relationship between macroeconomic variables and precious metals prices in developed and emerging markets for selected economies. Thirdly, the study tests the combined effect of macroeconomic determinants on precious metals prices in both developed and emerging countries.

1.3.1 Market Efficiency & Forms of EMH

The efficient market hypothesis (EMH) has been a cornerstone of financial economics for decades. In the 19th century, many financial economists and academics broadly acknowledged the existence of the efficient market hypothesis (EMH). ''Market efficiency" is derived from the efficient market hypothesis (Kliger and Gurevich, 2014). The concept of EMH was introduced by Fama (1970) in his influential paper "Efficient Capital Markets." He defines market efficiency as "a market in which prices always "fully reflect" available information is as an "efficient." In addition, he examined the empirical findings based on Fama (1965) efficient market hypothesis paper. Subsequently, many researchers researched described the concept of market efficiency in their studies (Jensen, 1978; Malkiel, 2003). Jensen (1978) reported that in an informationally efficient market, it is impossible to make supernormal economic profits by an investor using share price information. In an efficient market, security prices fully and accurately reflect all relevant information (Malkiel, 2003). Timmermann and Granger (2004) suggested that information is a yardstick for testing associated economic profits that is market efficiency.

However, Fama (1970) and Roberts (1967) subdivided EMH into three forms of market efficiencies: weak, semi-strong, and strong forms. These types of EMH vary in different markets as the information availability varies, they all rely on the inclusion of information in market prices. The weak-form EMH implies that all past prices are fully and immediately reflected in the current price. As a result, the returns are unpredictable, and no investor can consistently make abnormal profits by exploiting past information.

Humphreys (1987) notes that prices only take account of historic price moments and trading volume information, so investing in a financial asset, it is impossible for the investor to earn abnormal profits consistently as other investors have access to the same information. In addition, investors cannot predict the market moments based on historical time series, so technical analysis strategies are redundant. The semi-strong market efficiency postulates that past and public information are fully and correctly incorporated into current prices. Investors cannot earn consistently abnormal returns through using investment strategy based on public information set. Therefore, in a semi-strong form efficient market, fundamental analysis is redundant. Finally, the strong form of market efficiency assumes that the current prices fully and accurately reflect past, current, public and private information. Therefore, predicting future prices using past information is not possible as share price movement will follow random walk hypothesis. Only insider trading will lead to consistently abnormal returns.

Market efficiency (also known as return predictability) has a considerable impact on the speed with which information is transmitted and the availability of profit opportunities in the precious metals market. Investors have been attracted to four precious metals (gold, silver, platinum, and palladium) due to their hedging ability against inflation and economic downturns (Conover et al., 2009). In the past major economic emergencies like the Asian financial crises (also called Asian Contagion) and financial crises of 2007-2008 in the US stock market forced hedgers and speculators to think about other investment opportunities for their portfolio investments.

Gold and silver have been prominent precious metals over the years, especially in times of uncertainty in the financial market. Recently, platinum and palladium have received the attention of investors as they offer different returns and volatility directions in times of crises (Arouri et al., 2012). Hillier et al. (2006) and Daskalaki and Skiadopoulos (2011) suggested that precious metals have a significant power to improve the efficiency of investors by providing a higher reward-to-risk ratio than other investments. In addition, they reported that gold, silver, and platinum returns have low correlation with stock returns because of their diversification characteristics and the ability to hedging.

Shafiee and Topal (2010) reported that precious metals had become attractive and vital investment products, with the emergence of Exchange Traded Funds (ETFs) boosting investors' demand for gold and silver. Morales and Andreosso O Callaghan (2011a) also investigated that precious metal markets outperformed other major financial markets during the global financial crisis, indicating that precious metal markets have a role to play in the context of risk diversification. Agyei-Ampomah et al. (2014) tested the performance of three precious metals (gold, silver, and platinum) in the period of uncertainty in the market and found that silver and platinum offer investors better returns for their bond market losses than gold.

Literature on market efficiency suggests there is a considerable literature that examines financial market efficiency but there is limited research that has examined the efficiency of precious metals market across developed and emerging markets. The earlier study by Charles et al., (2015) investigated the weak form efficiency for three precious metals (gold, silver and platinum) in the United States. However, this thesis extends the literature by testing the weak form of efficiency for four precious metals (gold, silver, platinum, and palladium) across developed and emerging markets.

1.3.2 Macroeconomic factors and Metal Prices

Macroeconomic factors have a considerable impact on the prices of different metals and their trading volumes Fleming and Remolona (1997). Researchers have incorporated the significance of macroeconomic factors to explain the price movement of precious metals, see, for instance; Tan and Ma (2017) research suggested that macroeconomic shocks resulting due to uncertainty, would impact the returns of commodity prices and that most of the time this trend exist in those states where the level of un- certainty is high as compared with low-uncertainty states. However, Tan and Ma also confirmed that investment in precious metals is a safe haven for investors in the short and long run. Batten et al. (2010) examined the instability in prices of precious metals (gold, silver, platinum, and palladium) monthly, and the study found that their macroeconomic factors (business cycle, monetary environment, and financial market sentiment) impact on the fluctuation of precious metals pricing.

There is also a wide impact of macroeconomic factors on the prices of various treasury bonds and the data of unemployment and inflation after the announcement of economic variations Becker et al. (1996). Similarly, Balduzzi et al. (2001) analysed the impact of macroeconomic announcement on prices and volume of trading of bond prices. In this regard practitioners also investigate various data sets of precious metals e.g., silver and gold to investigate their response to change in the macroeconomic factors e.g. CPI, unemployment rate, GDP and other factors Steindel et al. (2000). Yin and Han (2016) also proved a significant impact of macroeconomic factors on commodity markets in China, whereas US macroeconomic factors have more impact on the commodity market than China in terms of the size of coefficients and their level of significance.

A prudent investor cannot ignore the element of inflation whilst constructing their portfolio. Inflation is directly related to the buying power of buyers, and it has a noteworthy impact on the behaviour of investor, who wants to invest in the commodities (Delatte and Lopez, 2013). Many researchers (Aktürk, 2016; Bampinas and Panagiotidis, 2016; Brown et al., 2016; Raza et al., 2017; Alagidede and Panagiotidis, 2010) reported in their research that stocks movement are correlated the change in the rate of inflation. In commodity market, only gold prices tend to mitigate inflation except when there is a large inflation shocks exist (Iqbal, 2017). Ranson and Wain- right (2005) also reported that investing in precious metals such as gold, silver, and platinum can insulate investors from the effects of inflation in times of economic un- certainty. Narayan et al. (2010) used different methods to test the market efficiency of gold, primarily when it is used with the oil prices. Narayan's study explained that the high level of oil prices leads to an increase in inflation, and this trend will automatically push the price of gold upward. Potential investors are encouraged to incorporate precious metals in their portfolios due to their ability to withstand inflation. The study also suggested that there is a correlation between precious metal prices and oil prices. Price of gold varies inversely with the price of oil and vice versa.

In contrast, if we see the south most region of African continent, their export is highly dependent on the two precious metals - gold and platinum. This research provides a more detailed comparison of views that whether these two precious metals (gold & platinum) can be useful for the economy stakeholders to forecast inflation for South Africa domestically or not. Furthermore, the study finds that forecaster must consider other uses of precious metals (gold & platinum), therefore, the metals should be taken into account whilst forecasting domestic inflation (Balcilar et al., 2017). The relevance of silver in diverse stock market scenarios was investigated by Bailey and Bhaopichitr (2004), who determined whether or not this precious metal has the power to decide the projected risk premium in the stock market. As a result of their investigation, Bailey and Bhaopichitr found that silver has a considerable impact on the stock market when it comes to forecasting changes in trade, economic growth, and inflation.

Past studies have shown that commodity prices change with the movement of interest rate, Akram (2009) suggested in his research that decline in real interest rate led to increase in the commodity prices. Moreover, Akram finds that metal prices fluctuated more a as expected in response to interest rate changes. Scrimgeour (2015) also suggested that metal prices are more responsive against interest rates as compared to agriculture commodities.

1.3.3 Nominal Interest Rate

In developed economy, Koutsoyiannis (1983) found that nominal US interest rate are correlated with precious metals. The real interest rate also has positively impact on precious metals prices, and whenever investors invest in the Exchange Trade Funds (ETF) or hold precious metals as an investment asset, there opportunity cost is always the interest rate because they could earn more from holding any other currency on deposit (Diba and Grossman, 1984). Contrary to this argument researcher claim that there is no substantial relationship between gold and the interest rate (Lawrence, 2003). Sari et al. (2010) employ GARCH-based models to examine the conditional volatility and instability of interest rates in the economy and its effect on the prices of three important metals (silver, gold, and copper).

1.3.4 Interest Rate

Commodity portfolio managers have more opportunities to invest in precious metals like Gold and Silver than copper (also known as semi-precious or industrial metal) to mitigate the risk in bad times. Moreover, gold and silver are less sensitive commodities to bad or good news, especially in short. They also revealed that an increase in the interest rate slows down the price volatility of the metal market, whereas oil shocks have encouraged the investors to invest in precious metals like gold and silver to diversify their portfolio.

1.3.4.1 Exchange Rate

In emerging economies, Sari et al. (2010) observed both short and long-run information between uncertainty in Brent oil prices, Turkish interest rate, the Turkish Lira or the US dollar exchange rate, and spot prices of gold and silver. Sari et al. collected daily data between March 2003 and March 2007. The evidence of Sari et al. showed that silver prices are adversely affected by fluctuations in oil prices, as it has a vital role in the industrial sector of Turkey. In the short run, the silver spot price has a strong positive impact on the Brent oil prices as quoted by Istanbul Gold Exchange IGE. Gürkaynak et al. (2005) examined the response of financial markets to monetary policy surprises. Romer and Romer (2004) study showed that a rise in the federal funds rate target might raise the interest rate by raising expected inflation.

Contrary to this argument, Gürkaynak et al. (2005) anticipated that a rise in the federal funds rate target leads to decreased long-term projected inflation. Thorbecke and Zhang (2009) have picked the same hypothesis of the previous two theories conducted by Romer and Romer (2004) and Gürkaynak et al. (2005), considering the time between 1974 and 1979 as well as between 1989 and 2006. Furthermore, Thorebecke and Zhang found that an increase in funds rate in 1970 has raised the prices of gold and silver, a finding in line with Romer and Romer (2004). On the other side, an increase in the federal funds rate resulted in a reduction in the price of silver in anticipation of an increase in short-term real interest rates in 1989 and 2006, respectively, and this result endorsed the theory of Gürkaynak et al. (2005).

1.3.5 Macroeconomic News

Past literature showed that macroeconomic news impacted the prices of precious metals, especially gold and silver. After reviewing the literature regarding the impact of the unemployment rate on metal markets, the developed economy was mainly examined, particularly in the US metal market. Therefore, there is a substantial impact of US macroeconomic news announcements on the return, unemployment rate containing enough information to cause volatility in the metal market (Elder et al., 2012). Authors examined 23 different US macroeconomic announcements and found that employment reports significantly impacted the dynamics of return volatility of precious metals (Cai et al., 2001).

Christie-David et al. (2000) argued on this point by using intraday data (1992-1995) and reported a significant impact of the macroeconomic news release on gold and silver futures prices. Moreover, Christie-David et al. emphasizes that fund managers should include unemployment reports when making the construction portfolio. However, Smales and Yang (2015) examined the prices of gold which respond briskly due to the macroeconomic announcements in the commodity market.

Labys et al. (1998) have found that macroeconomic shocks can have an impact on both precious and industrial metals at the same time. In addition, Agyei-Ampomah et al. (2014) suggested that industrial metals, particularly copper, are considered hedging and safe havens for sovereign bond loss. The common characteristics of both metals can lead to the transfer of information. However, Tiwari et al. (2021) examined volatility spillovers between precious metals and industrial metals markets over the period 1993 to 2019. They concluded more robust connectivity in the industrial metal market than the precious metal market. Secondly, during the Asian financial crisis of 1997 and the global financial crisis of 2008, the volatility spillovers of both metals (precious and Industrial) exhibited distinct dynamics; and, more than industrial metals, the volatility spillovers in precious metals increased sharply, providing compelling evidence that the two metal groups have distinct hedging properties. Thirdly, precious metals act as the net information transmitter, especially during crises, meaning that the information of precious metals appears to help predict the price volatility of industrial metals. Finally, they found that the long-term and short-term components of the precious and industrial metals' volatility spillovers were broadly similar. Since precious metal prices tend to move in different directions depending on their fundamentals, there is little spillover between them when prices move in different directions.

Macroeconomic environment is not limited to the factors studied in this thesis. In literature there are several macroeconomic variables that affect the precious metals market. For example, exchange rate movements impact economy at large and precious metal prices. In addition, precious metals prices are also impacted by geopolitical tensions such as uncertain economic condition during 2004 that lead to producer de-hedging gold as a result gold price reached to 16 years high (World Gold Council, 2002). There are large number of factors such as employment rates, GDP, consumer price indexes, and personal income, just to mention a few, all influence precious metals market, as demonstrated by Cai et al. (2001). However, as is the case in the literature only relevant variables are considered for this study and the choice is consistent with the earlier literature (Vigne et al., 2017; O'Connor et al., 2015; Hussainey et al., 2009; Gan et al., 2006). The variables chosen for this study are based on the close proximity to the topic under investigation. Therefore, this thesis primarily investigates the relationship between the prices of four precious metals and seven macroeconomic variables of the economy, that have been employed in studies which examined market efficiency for financial market Charles et al. (2015). This study employs the Consumer Price Index (CPI), Industrial Production (IP), Share Price (SP), Long-term Interest Rate (LIR), Short-term Interest Rate (SIR), and Unemployment Rate (UR).

This in-depth study found that market efficiency for four precious metals differ for developed and emerging economies. The difference could be attributable to different economic environment, technologies and the financial markets. Moreover, the empirical findings show that macroeconomic factors have relationship with precious metals prices for developed and emerging economies, although patterns vary by region. The evidence also suggests that the long run cointegrating relationships are fragile and differ across established and emerging economies. The causality test results between four precious metals and major macroeconomic indicators differ, depending on the country and length of the frequency distributions used. Overall, the finding of this thesis provides an in-depth and extended evidence that the relationship between macroeconomic variables and precious metals exist and the ETFs, via financial markets mediate market efficiency that has implications for institutional as well as individual investors when constructing the portfolios that includes precious metals. However, at the same time the study also raises several questions related to precious metals market and its innovative characteristics and their relevance which are to be explored in the future.

2 Chapter 2: Market Efficiency of Precious Metals: Empirical Evidence from Developed and Emerging Economies (Paper 1)

Abstract

Precious metals (gold, silver, platinum, and palladium) are critical components of portfolio selection and management. Individuals as well as institutions have been attracted precious metals due to their hedging ability against inflation and economic downturns. This empirical research examined the weak-form efficiency of precious metal markets using the Automatic Portmanteau test, Automatic Variance Ratio test, Autoboot Variance ratio test and Generalized Spectral Shape test. In addition, the study examined the weak-form efficiency and return predictability of daily gold, silver, platinum and palladium spot price return series across developed and emerging markets. The findings of this study suggest market efficiency for four precious metals varies over time across developed and emerging markets. The variation for market efficiency could be attributable to cyclical movements in economies due to technology and business boom or burst events. The findings could also be interpreted as the markets are fragmented and not interconnected due to a variety of factors such as regulations, lunar cycles, market complexity, and other factors that are difficult to predict.

Keywords: Adaptive markets hypothesis, Martingale difference hypothesis, Market Efficiency.

2.1 Introduction

The study of the market efficiency of precious metals investigates whether the precious metals markets are efficient across developed and emerging markets. Though the market efficiency topic is extensively studied for stock market share price movements, but the efficiency of precious metals is an emerging research topic. In a recent study, Charles et al. (2015) investigated the market efficiency of gold, silver, and platinum in the US markets, but there is a gap in the literature that investigates the same for developed and emerging economies at large. Therefore, the uniqueness of the present study is that it covers palladium and investigates the efficiency of the precious metals market in both developed and emerging markets.

Precious metals are important in the selection and management of investment portfolios. These metals have recently gained importance globally for investors due to their distinct properties (Emmrich and McGroarty, 2013). Over the last few decades, investors have increased their holdings of precious metals, empirical evidence suggested they have ability to hedge against inflation and economic downturns (Conover et al., 2009). Moreover, these metals have a remarkable ability to improve the portfolio's efficiency for the investors in terms of a higher reward-to-risk ratio (Hillier et al., 2006; Daskalaki and Skiadopoulos, 2011). Shafiee and Topal (2010) reported that precious metals have become more attractive and essential investment products, especially with the emergence of Exchange Traded Funds (ETFs) boosting investors' demand for gold and silver.

Regarding these precious metals markets, Hillier et al. (2006) discussed a variety of important research concerns, such as their involvement in diversification, hedging, and risk management (see also Marshall et al., 2008; Belousova and Dorfleitner, 2012). The one of the research issues that Hillier et al., (2006) observed is the feature of the return distribution, a basic relevance to the market players. In particular, the efficiency of the market, also known as the predictability of returns, has significant repercussions for both the rate at which information is disseminated and the presence or absence of possibilities to make a profit in the markets. Platinum, on the other hand, is largely utilized as a commodity for industrial usage, whereas gold and silver have historically been viewed as an "investment of last resort" (Hillier et al., 2006).

Metals are necessary for industrial processes and storage of value. Thus, they have and will continue to play a significant role in the economy and civilization as long as they are available (Aggarwal and Soenen, 1988). As a result, it is critical to grasp how metals are valued and exchanged in the marketplace. Moreover, metals trading is crucial since they represent commodities with a wide range of industrial applications and separate significant asset classes for investors. Since prices and volatility for different metals do move synchronously, therefore, they offer the opportunity for risk diversification (Batten et al., 2010).

Gold and silver have been prominent precious metals over the years, especially in times of uncertainty in the financial market. Among four precious metals, these two metals (gold and silver) trade 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 (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 (Vigne et al., 2017; Arouri et al., 2012). Morales and Andreosso O Callaghan (2011b) indicated that silver, platinum, and palladium outperformed other major financial markets during the global financial crisis. Precious white metals (silver, platinum, and palladium) have started to perform better as an investment commodity after the silver ETF was introduced in April 2006, followed by platinum and palladium ETFs in 2010 (Vigne et al., 2017).

Agyei Ampomah et al. (2014) conducted a study examining three precious metals (gold, silver, and platinum) during a time of market instability from 2005 to 2011. They found that palladium offers investors better returns for their bond market losses than gold and silver. Agyei-Ampomah et al. also reported that gold, silver, and platinum returns have a low correlation with stock returns because of their diversification and hedging tool capability. However, several research questions were raised by Hillier et al. (2006) concerning the precious metals markets and their significance in portfolio diversification, hedging, and risk mitigation process. For instance, how important is gold in today's financial markets? Are the precious metals markets efficient? Do precious metals offer additional diversification benefits than a portfolio comprised entirely of financial assets?

Thus, a gap has already been identified to extend research on the relationship with precious metals. Furthermore, the features of return distributions are a critical concern for market participants within these study questions. Hiller et al. also reported that market efficiency (i.e., return predictability) is a significant factor in the speed with which information is processed in financial markets. It enables participants with superior information to earn supernormal profits case with the precious metals market. As a result, this study is significant; it addresses an important role by testing whether precious metals markets in developed and emerging markets are efficient and their consequences for portfolio diversification.

The literature on market efficiency has also been used to test the pricing of commodities. According to empirical evidence presented in the literature, energy commodities have been the most efficient, followed by soft commodities as the second most efficient (i.e., grains and metals). Furthermore, in the precious metals markets, the research on EMH is sparse (Tschoegl, 1980; Ho, 1985a; Solt and Swanson, 1981; Aggarwal and Soenen, 1988b; Smith, 2002). The emergence of Exchange Traded Funds and a revolution in information technology have changed EMH for precious metals; information about the supply and demand of metals is rapidly processed; thus, this makes a case for new research. To bring more realism and practicality, the new research needs to evaluate the outliers such as the social norms, holding gold, environmental, and other macroeconomic factors in relationship to precious metals. However, in the past, the focus of research mostly remained on the prices in the UK and the US markets (Charles et al., 2015).

The study by Charles et al. (2015) has attempted to investigate gold, silver, and platinum through the use of automatic portmanteau and variance ratio tests. However, the study had not included palladium, nor have they investigated precious metals' role in both developed and emerging markets. In addition, the results of previous empirical studies on the weak-form efficiency of precious metals markets, such as the ones conducted by (Tschoegl, 1980; Solt and Swanson, 1981; Ho, 1985; Aggarwal and Soenen, 1988; and Smith, 2002), are not valid due to small sample data properties that were used for the statistical tests. This study addresses a significant gap in the literature related to precious metals price efficiency across developed and emerging economies and analyzes the level of weak-form efficiency for four precious metals: gold, silver, platinum, and palladium (GSPP). The weak-form efficiency instantaneously reflects all past price and return information in the current price. Hence, returns are unpredictable, and investors cannot regularly achieve supernormal profits by leveraging historical price information (Fama, 1970).

Moreover, this study tests the GSPP's market efficiency (i.e., return predictability) using the martingale difference hypothesis (MDH) across developed and emerging markets. The study adopts the most recent techniques, 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) and Kim et al. (2011). It also 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) (iii) the Wild Bootstrap Automatic Variance Ratio test by Kim (2009) and Wild Bootstrap Generalized Spectral test by Escanciano and Velasco

(2006), an improved version of the Durlauf (1991) test. Moreover, these tests have been used in empirical finance to evaluate asset return predictability (see for example: Kim, 2009; Lo and MacKinlay, 1988).

The novelty of this study is that it employs the automatic variance (AVR) test developed by Kim (2009), the automatic portmanteau (AQ) test developed by Escanciano and Lobato (2009), and the generalised spectral (GS) test developed by Escanciano and Velasco (2006) to examine return predictability following the Adaptive Market Hypothesis (AMH). For the first time, we use the GS test to examine both the linear and non-linear autocorrelation structures of GSPP's across developed and emerging economies.

To gain deeper insight, we also examine the predictability of returns over time using two-year rolling window approach of each test statistic across an extended sample period to determine return predictability. Thus, we can observe time-varying predictability of precious metals returns and also determine if any patterns in return predictability varies over time. This research employs the sample data set for February 1, 1968, to December 2018. However, the sample data varies across metals and markets. Therefore, we have included the financial crisis of 2008-09 an approach consistent with Hood and Malik (2013).

Given the recent event of Brexit, it has never been investigated for EMH concerning precious metals. Additionally, we found a scarcity of studies addressing the influence of the 2007–2008 financial crisis on the precious metals markets. Therefore, the growing role of precious metals to hedge risks, there is a strong case to test their efficiency, across developed and emerging economies.

The study is structured as follows: Section 2.2 covers literature dealing with the background on precious metals and adaptive markets hypothesis in detail. Section 2.3 describes the methodology and data in detail. Section 2.4 considers the results derived using the dataset and reports and evaluates the empirical findings. Section 2.5

considers the results, their application and section 2.6 limitations and concludes.

2.2 Background on precious metals and adaptive markets hypothesis

Over the centuries, precious metals have been considered a store of wealth in uncertain economic conditions due to their intrinsic value. Compared to other types of assets (e.g., fiat money), gold has operated as a reservoir of wealth and a vehicle of exchange (Goodman, 1956; Solt and Swanson, 1981). A "Choice in Currency," as recommended by Hayek (1976) for the purpose of limiting inflation, a medium of exchange existed in many parts of the world until the recent past. Numerous commodities like gold, silver, copper, tobacco, cattle, salt, and tea were utilized as currency (Bank and Davies, 2002; Crockett, 1975).

Metals are necessary for industrial processes and storage of value. Thus, they have and will continue to play a significant role in the economy and civilization as long as they are available (Aggarwal and Soenen, 1988). As a result, it is critical to grasp how metals are valued and exchanged in the marketplace. Moreover, metals trading is crucial since they represent commodities with a wide range of industrial applications and separate significant asset classes for investors. Since prices and volatility for different metals do move synchronously, therefore, they offer the opportunity for risk diversification (Batten et al., 2010).

In the United States, merchants/private banks pioneered the practice of issuing paper money redeemable for the commodity that defined their unit of value (Crockett, 1975). Prices of precious metals have been exceptionally volatile after President Nixon ended the dollar's convertibility into gold and international payments made by private banks in the national currencies of the so-called 'strong' currency countries rather than exchanges of gold by central banks (D'Arista, 2009).

Numerous studies have reported that uncertainty in market conditions such as changes in international institutions, macroeconomic factors (i.e., Exchange rate and business cycle fluctuations, the monetary environment, and financial market sentiment) and different global-political factors may impact on the efficiency of market and other market features (see for example, Kaufmann and Winters, 1989; Rockerbie, 1999; Riley, 2009; Hood and Malik, 2013). However, due to these changes in the market, new information is incorporated, which directly impacts the prices.

Precious metals have several beneficial properties, including the fact that they are considered a source of wealth, and during a financial crisis when all other assets are subject to market volatility, they sustain their true value, thus protecting the owner's purchasing power (Shahid et al., 2019). As gold has distinct qualities and maybe quantified in monetary terms due to its role as a "means of exchange, a unit of value, and a store of wealth" throughout history (Goodman, 1956; Solt and Swanson, 1981). Additionally, at times of economic/political crises and stock market crashes, gold plays a critical asset-allocation role while also providing key portfolio diversification characteristics (ciner, 2001).

Many economists and the layperson at large believe that gold is the dominant precious metal. However, in recent times sliver has played a significant role in global markets, mainly because of the increase in its industrial use; thus, its value has gained importance, and it is treated as a financial instrument for investor portfolio investment (Sari et al., 2010). The technological innovation, greater usage, for example, in batteries, electronics, solar energy and medicines, has conferred unique characteristics to silver (Shahid et al., 2019) and a storage of value (Cochran et al., 2012). Thus, since the 1930s, silver markets have been actively trading 24 hours a day in London, Bombay, Shanghai, San Francisco, and New York. Currently, the major active silver markets are London, Shanghai, COMEX, the Multi Commodity Exchange of India, and TOCOM in Japan (Vigne et al., 2017).

Platinum is twenty times rarer than gold and more laborious to extract, in its pure form than gold and silver (Welch and Compton, 2006). Production of platinum reached a peak of approximately 514 tonnes in 2006, which was a record high. Following that, production decreased to fewer than 500 tonnes. Since this metal is worldwide renowned for its purity and uniformity, it is also suitable as a medium of trade (Shahid et al., 2019). This metal is also used in the production of approximately 20% of consumer items, which increases its importance. Even though precious metals have distinctive and varied qualities, these features are heavily reliant on the economic and political situations that prevail at the time (Urquhart, 2017).

The price of the platinum usually follows the price of other precious metals, in particular with gold (Sari et al., 2010). However, palladium is inferior relative to platinum but mostly it is used for catalytic converters in the automotive industry (Summers et al., 1988). Therefore, palladium has gained against other precious metals. It also has usages within dentistry and the jewelry industry, especially it has a high demand for dentistry because of its naturally whiting properties. Furthermore, when it alloyed with gold, it produces ‘white gold, which is expensive in the Jewelry industry. Moreover, palladium jewelry also competes with platinum Jewelry in China (Corti, 2005).

Due to diverse usages and exclusive features of the precious metals, their price and demand is determined by the prevailing economic and political conditions. In this study, the adaptive market hypothesis (AMH) offers an appropriate model for examining the return predictability of metal markets. Lo, (2004) suggests investors are motivated by self-interest, learn from their mistakes, and adapt to change. A test of the efficient market hypothesis typically results in a dichotomous judgement, meaning that the market is assessed to be either completely efficient or inefficient, which is implausible conclusion. Nonetheless, under the AMH, the market could exhibit behavior that deviates from the state of perfect efficiency, depending on the circumstances of the market and the participants access to information and behaviour. The AMH was developed by combining the idea of evolution with the concept of limited rationality (Simon, 1955); AMH studies the decision making of investors when faced with limited access to information or limited ability to interpret information to optimize return (Hillier et al., 2006). Whereas the martingale difference hypothesis (MDH) test (mentioned in the introduction section) has been used with time series as a best predictor with the precious metals data, an approach consistent with Charles et al, (2011 and 2015).

Lo, (2004) claims that an evolutionary process of trial and error and natural selection yields a desirable result. Natural selection is the mechanism by which the strongest and healthiest individuals are preserved, as well as the method by which the quantity and make-up of market participants are established. Investment decisions are made by market players using heuristics to adapt to a dynamic environment that is continually shifting. Opportunities to make a profit do, on occasion, arise when the evolutionary viewpoint is taken into consideration. Even if new opportunities are always being produced, old ones tend to vanish after being taken advantage of by investors. This is because the composition of market participants, the institutions that serve them, and the circumstances in which businesses operate are constantly shifting.

The theory of EMH has provided insight into the role of information to effect price change within financial markets. Thus, it has been dominant in the literature of finance 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 have produced conflicting conclusions concerning the validity of this theory, which has resulted in a continuing disagreement between the EMH and behavioural finance school of thoughts. Few research studies provide evidence that corroborate the EMH (Ayadi and Pyun, 1994; Cheung and Andrew Coutts, 2001; Fama, 1970; Granger and Morgenstern, 1963; Hawawini, 1984; Lock et al., 2007; Poon, 1996; Stachowiak, 2004). However, several studies have also highlighted both the deviation from the random walk (Al-Ajmi and Kim, 2012; Bley, 2011; Butler and Malaikah, 1992; Claessens et al., 1995; Jarrett, 2010a; Lovatt et al., 2007; McPherson et al., 2005; Smith, 2002; Squalli, 2006) and the possibility of effective investment techniques (Asem and Tian, 2010; Cheema and Nartea, 2017; Chopra et al., 1992; Cooper et al., 2004; De Bondt and Thaler, 1985; Jegadeesh and Titman, 2001; Lakonishok et al., 1994; Shi and Zhou, 2017).

Fama (1988) claimed that the EMH is still valid because the abnormalities reported in multiple studies are not stable and vanish when changes are made to the model, sample, or data frequencies. Subsequently, behavioral finance challenged the notion of 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 with evolutionary, adaptation, competitiveness, and natural selection principles. AMH brings together the concepts of behavioural 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).

The weak form of EMH has been widely tested using the martingale difference hypothesis (MDH), which states that current price is the best forecast of future price (Escanciano and Velasco, 2006). The Martingale Difference Hypothesis (MDH) is important to economic models that test rational expectations. According to the MDH, the unconditional expectation is the best predictor of the future values of a time series given the previous and current information set. This is measured by the mean square error, which is a measure of how accurate the prediction is. In the statistical literature, the MDH is referred to as conditional mean independence, and it denotes that information from the past and the present do not contribute in any way to the process of forecasting future values (Escanciano and Lobato, (2009).

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). 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 demonstration 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. Thus, to get a satisfactory outcome can be costly, and market players who have inadequate resources of information or do not have enough capacity to process the information, are solely engaged in attaining that satisfactory outcome. Numerous studies have found the weak-form efficiency of financial assets, which was initially related to whether stock prices are randomly created in the first place (Ayadi and Pyun, 1994; Belaire-Franch and Opong, 2005; Lo and MacKinlay, 1988a; Ntim et al., 2007; Ntim, 2012; Smith, 2002; Urrutia, 1995). Earliest literature includes studies by Tschoegl (1978); Booth and Kaen (1979); Solt and Swanson (1981) have investigated the weak-form efficiency of the gold market, even though their findings were varied. Tschoegl (1980) empirically investigated the price of gold from the perspective of weak-form efficiency. Besides, he observed a series of twice-daily prices for gold and determined whether successive price changes are independent or not. However, if prices are not independent, the investor can 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.

Therefore, it is treated as a financial asset in the portfolio investment as certain financial assets pricing variations can impact gold price changes by portfolio adjustment. However, if the gold market is efficient, any price movements in other assets will have simultaneous effects on gold. In an increasingly efficient market, past price fluctuations of other financial assets are not relevant in anticipating future gold price changes (Ho, 1985). Moreover, several studies have examined the weak form of the EMH in relation to Islamic indexes (Hassan, 2002; El Khamlichi et al., 2014; Rizvi et al., 2014; Jawadi et al., 2015).

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); Ho (1985) 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 outdated 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 re- turn series (Ntim, 2012; Ntim et al., 2007; Savit, 1988), which however result in false rejection (or acceptance) of the random walk hypothesis (Chow and Denning, 1993; Hsieh, 1991; Luger, 2003; Wright, 2000). However, market conditions have changed overtime because of the enhancement in technology, advancement in the 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; Shafiee and Topal, 2010; Wang et al., 2011; Parisi et al., 2008).

However, the findings of recent studies using modern statistical techniques are still generally mixed (Basu and Clouse, 1993; Christie-David et al., 2000; Mills, 2004; Narayan et al., 2010; Yu and Shih, 2011; Baur, 2013; Blose, 1996). 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.

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 Chang 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 context 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. There has been little behavioural finance study on these two metals, although Lucey and Dowling (2011) have looked into 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 from that, the mood proxies employed 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. Lucey (2010) established the existence of lunar cycles for the first time and discovered that moon cycles had no effect on platinum pricing.

Charles et al. (2015) found 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.

To explore the predictability of commodity markets, Zunino et al. (2011) used an innovative approach derived from information theory. The Zunino et al. study showed the efficiency ranking and reported that silver, copper, and cotton were 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 explore how the degree of predictability of returns have evolved through time in response to 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 mostly used in time series regression; the approach involves conducting repetitive regressions, with sub-samples of our original full sample. Furthermore, this study estimates the return predictability using time-varying measures in four precious metal markets—gold, silver, platinum, and palladium, in close association with the AMH. We employ the improved version of the efficient market hypothesis of Fama (1970), as suggested by Lo (2004). The significant implication of AMH is that return predictability may increase over time because of environmental changes and various other institutional factors.

2.3 Methodology and Data

We test the 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 also 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), (iii) The Wild Bootstrap Automatic Variance Ratio test by Kim (2009) and Wild Bootstrap 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 these studies have used time-varying measures of return predictability to examine the martingale difference hypothesis (MDH), a gap that is studied within this empirical research. 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, as a result of changes in the economy, politics, and financial events. This section of methodology contains the following subsections.

2.3.1 Data Description

In this subsection of methodology and data, we present the details of the data and their descriptive properties. We also offer empirical findings and discuss the consequences thereof. This study employs historical data on the daily prices of the four most traded commodities (gold, silver, platinum, and palladium) and examine daily spot prices of four precious metals for two categories of economies: developed and emerging markets. Developed markets are those markets that have 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. Secondly, emerging markets are economies that display few 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.

Charles et al. (2015) examined the weak-form efficiency of three precious metal markets gold, silver, and platinum as it is a safe haven for the investor's portfolio managers and institutions. Moreover, Charles and Darne (2009) examined the weak-form of efficiency for five emerging markets particularly in Latin America and reported that four Latin Markets (i.e., Argentina, Brazil, Chile and Mexico) are not weak-form efficient. However, they were not able to conclude for Ecuador as the results are mixed and they did not consider the possible structural breaks because of different financial events, which can affect the VR tests.

The sample data comprised of daily closing spot prices and their log returns for four precious metals - gold, silver, platinum, and palladium. The data covers 9 developed and emerging economies - UK, USA, Australia, Switzerland, Japan, India, China, Hong Kong, and Mexico. All daily prices of four precious metals are quoted in the respective local currencies. The pricing data series spans over 50 years, however, the range of years cover for each country varies; the UK's range is the longest from 1968, to 2018 (13,304 daily observations), whereas for Australia the data is from 2008 to 2018 (2871 daily observations) the shortest period. The data for this study was obtained from Thomson Reuters Financial DataStream. Figure 2.1 displays the metal prices and their log returns. The data period cover for each precious metal varied as the commencement of trading dates were different. The trading for gold and silver commences in 1968 and for platinum data begins in 1976, and palladium starts in 1987.

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 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 is ended. Through this method, 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 the 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).

2.3.2 Descriptive Statistics

In Table 2.1, we present descriptive statistics for the return series measured as the first logarithmic difference in the daily closing prices of four precious metals - gold, silver, platinum, and palladium.

For gold and silver, findings show a higher mean return in emerging markets like India, China, and Mexico than developed markets - UK, USA, Australia, Switzerland, Japan, and Hong Kong. All four precious metals exhibit the least volatility in emerging and developed markets in terms of a standard deviation. All return series exhibit substantial skewness, with negative skewness observed for gold, silver, platinum, and palladium in developed and emerging markets. Moreover, positive skewness for the gold UK, Australia, Switzer- land, and India, Silver in Australia, Platinum Hongkong, and Palladium in Australia suggest asymmetric shape (with a longer left tail for gold, silver, and palladium) in the empirical distribution of the returns.

Table 2.1: Descriptive Statistics for Precious Metals Returns

Metals	Country	Mean	Median	SD	Maximum	Minimum	Skewness	Kurtosis
	UK	0.0055	0.0000	0.2193	4.1024	-3.8983	0.8370	48.4022
	Australia	0.0021	0.0026	0.1544	1.9122	-1.7869	0.1623	25.0564
Gold	Switzerland	0.0005	0.0000	0.2039	3.9014	-2.9162	0.3464	44.5111
	Japan	0.0014	0.0047	0.1364	1.5171	-1.1491	-0.4081	19.1363
	China	0.0043	0.0000	0.2047	2.1182	-1.8222	-0.2190	13.5699
	India	0.0028	0.0000	0.0683	0.7904	-0.5662	0.0551	15.8855
	Mexico	0.0005	0.0000	0.1496	8.5076	-8.5076	-0.0077	32.1039
	UK	0.0123	0.0000	0.0214	0.4116	-0.4086	0.0133	38.8980
Silver	Australia	0.0123	0.0000	0.9255	23.3799	-19.1995	1.0671	69.7032
	Switzerland	-0.0002	0.0000	0.2977	2.0653	-3.7208	-0.9490	14.0856
	USA	0.0083	0.0000	0.8509	5.8986	-10.1381	-0.5257	10.9786
	China	0.0001	0.0000	0.1887	1.0234	-1.2879	-0.4984	10.1886
	India	0.0025	0.0000	0.1510	1.1480	-1.4696	-0.5455	13.5693
Platinum								
	UK	0.0029	0.0000	0.2519	2.4415	-2.4152	-0.2889	12.3116
	Australia	0.0020	0.0013	0.1811	1.6714	-1.6306	-0.0117	10.9582
	China	0.0001	0.0000	0.2251	1.7515	-2.8522	-0.6929	15.4652
Palladium	Hongkong	0.0019	0.0000	0.2018	2.4089	-2.0489	0.0137	13.4597

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

Hence, Maximum returns are negatively skewed, indicating that extreme negative output changes tend to be higher than extreme positive outputs. Excess kurtosis is found for all return sequences, implying that their empirical distributions are leptokurtic, i.e., substantially fatter tails than the normal distribution.

2.3.3 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 (1988a). Traditionally, the portmanteau test of Ljung and Box (1978) and variance ratio test of Lo and MacKinlay (1988a) have been extensively used in the empirical finance for the evaluation of asset return predictability. However, both these tests failed to per- form 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 possessed more power and size properties under each category. Numerous studies have contributed to these tests. For example, 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 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. Further- more, 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) conducts 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 (1993a); 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 bootstraps 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.

2.3.4 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 (1988a) 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 (1993a) extended the variance ratio methodology of Lo and MacKinlay (1988a) 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 (2000a) 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 considered 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

$$V(k) = 1 + 2 \sum_{j=1}^{k-1}(1 - \frac{j}{k})\rho_j \qquad \textit{Equation 1}$$

Equation 1 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

$$VR(k) = 1 + 2 \sum_{j=1}^{k-1}(1 - \frac{j}{k})\,\hat{\rho}_j \qquad \textit{Equation 2}$$

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:

$$AVR(k) = T/\hat{k}[VR(\hat{k}) - 1]/\sqrt{2^d} \rightarrow N\,(0,1) \qquad \textit{Equation 3}$$

One of the primary drawbacks of the AVR test in equation 2 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 (1993b). Gonccalves and Kilian (2004b) 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 3) 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 boot- strapping approach of Kim (2006, 2009) had favourable small sample features.

2.3.5 Automatic portmanteau test (AQ)

One of the most significant disadvantages of the AVR test is that positive and negative correlations may cancel one other out, resulting in a inaccurate AVR test statistic. The automatic portmanteau test, 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 to modify 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 exist 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 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. (1977a); Davies and Newbold (1979); Ljung and Box (1978b); 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 ex- tension 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 limitations 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;

$$Q_\rho = T \sum_{i=1}^{\rho} \hat{\rho}_i{}^2 \qquad \textit{Equation 4}$$

In equation 4, 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).

$$Q_p = T \sum_{i=1}^{p} \hat{\rho}_i{}^2 \qquad \textit{Equation 5}$$

In equation 5, where $\tilde{\rho}_i^2 = \hat{\gamma}_i^2 / \tau_i^2$; $\hat{\gamma}_i^2$ is the estimator for the autocovariance of metal return of order i, and τ_i^2 is 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:

$$AQ = Q_{\tilde{p}}{}^* = T \sum_{i=1}^{\hat{\rho}} \tilde{\rho}_i{}^2 \qquad \textit{Equation 6}$$

In equation 6, where $\tilde{\rho}$ 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.

2.3.6 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 in order 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;

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

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

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

In equation 8, where $\gamma 0(x) = \left((T-J)^{-1}\right)\sum_{t=1+j}^{T}\mathrm{Y}-\bar{\mathrm{Y}}_{T-J}\Big)e^{ixY_{t-j}}$ 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 $H_0(\lambda,x) = \hat{H}\ (\lambda, x) = \gamma_0(x)\lambda$ where the test statistics is

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

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:

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

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.

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

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.

2.4 Empirical Analysis

2.4.1 Precious Metals Prices and Log Returns

Figure 2.1 depicts the metal prices, and their log returns for precious metals in sample for developed and emerging markets. The prices of three precious metals - gold, silver, and platinum depict instability in the 1980s in the developed markets, in particular the silver . The following subsections include a description of the pertinent points pertaining to each type of metal.

2.4.1.1 Gold

This extraordinary rise and fall in gold prices were driven by a confluence of significant geopolitical events, such as the Russian invasion of Afghanistan in December 1979 and the Iran hostage crisis, which was also noted by Baur and McDermott (2010). Gold prices experienced a severe correction from January to March of 1980 and have been on a downward trend ever since. This correction was due to by Paul Volcker's (Chairman of Federal Reserve from 1979 to 1987) decision to raise interest rates (from 13% to 20%) to control inflation, that lead to fall in consumer price index in March 1980, this corresponds to upward blip for gold as evidenced in Figure 2.1. However, by June 1980, the CPI had fallen by 2.6% (Nersisyan and Wray, 2022). This lead to a fall in gold prices, thereafter the prices will go remain stable throughout the 1980s

Figure 2.1 also illustrates the second historic spike at the start of 2008 and spanning, both developed and emerging markets. This increase is far more securely founded and less variable than the initial price spike that occurred in the year 1980. On March 17, 2008, the price of gold reached its all-time high, which was around $1011, and on September 18, 2008, the price of gold had its greatest day spike, which was over $70. The rise in the price of gold, both in the short term and the long term, may be attributed to several different causes.

There are two primary factors at play behind the substantial rise in the price of gold after the global financial crises 2008. To begin, investors have less faith in the reliability of the financial markets as a source of investment opportunities at times when global financial markets were crashing, and the worldwide economy was in recession. Because of this, investors turned to speculation or to any market that did not have significant liability or volatility, such as the market for gold. In other words, the gold market functions as a sort of insurance against excessive swings in the value of traditional assets during times of uncertain financial markets. Large corporations purchased gold as a hedge against fluctuations in the value of the US dollar and inflation for several reasons. The first of these is that the US dollar had become less valuable in comparison to other currencies. The second was that high oil prices have contributed to inflation worldwide. Hence, the trading of gold was considered as a counterbalance against fluctuations in the value of the US dollar and inflation, so offsetting any possible movement of actual value in the short-term market (Shafiee and Topal, 2010).

There are three primary factors that are likely to drive up the price of gold over the long run. The mine production has been steadily falling throughout the course of those years (after 2008). There are a number of causes that may have led to this fall in mine production, some of which include increased mining costs, less exploration, and problems in identifying new deposits. Second, both institutional and individual investors have logical expectations despite the unpredictability of the markets. Therefore, they consider gold to be more liquid or marketable than other financial assets, which is an advantage in a volatile financial market. In addition, investing in gold through gold Exchange Traded Funds (ETFs) became less complicated (Shafiee and Topal, 2010). As a reullt of ETFs, the demand for the precious metal has been bolstered (WGC, 2008).

2.4.1.2 Silver

Silver is also a well-known valuable metal due to its use in industry. Silver is less expensive as compared to gold. Figure 2.1 depicts spike in the silver markets across developed markets between 1979 to 1980s. Prior to 2007, the pricing information for silver in emerging markets like China and India was not available; as a result, those years are omitted in our study. In 1980, the "Silver Thursday", was one of the most publicized days when there was enormous price surge for silver; this was due to President Richard Nixon abandoned the Bretton Woods system and the gold standard, the US dollar started to float freely as a fiat currency in the 1970s. Policymakers grappled with plummeting currencies, stock markets, and savings during a decade of double-digit inflation. Throughout the 1970s, gold and silver prices moved up in tandem, demonstrated that they could be an alternative investment (The Gold Bullion Company, 2021).

The second spike in silver was seen in 2008 (see figure 2.1), and it was accompanied by a record inflow of over 93.1 million ounces (Moz) into the three main silver ETFs. This record inflow played a significant role in the high price average, as investors drove silver to its highest price in decades, both in terms of its daily price and its annual average. Moreover, the production of coins and medals reached an all-time high of 64.9 Moz in 2008, an increase of 63% over 2007. The increase in the number of people buying bullion coins for investment purposes in both the United States and Europe was the primary factor in this development. The demand for silver as an investment has remained high throughout 2009, the USA experienced almost 70% in the first quarter alone (The Silver Institute, n.d.). In 2009, the average price of silver was $14.67, making it the year with the second highest average price since the high point in 1980. The primary cause for the 53% increase in price was strong due to gains in investment as well as a rebound in demand for silver later in the year (Bampinas and Panagiotidis, 2015).

2.4.1.3 Platinum

Platinum and palladium are both members of the same family. The great majority of the industrial applications for both metals are found in the exhaust systems of motor vehicles, with platinum's applications also include lab equipment and electrical connections, amongst other things. Not one of them, however, has a pricing structure that is anything like the other (Oranje, Nel and Van Huyssteen, 2021).

Platinum price reached its all-time high ($2252 per ounce) in March of 2008 (see figure 2.1). This was not just the result of a weak dollar but also of production difficulties brought on by power shortages in South African mining operations. As a result of the severe sell off in November of 2008, the price dropped to $774 per ounce. Nonetheless, the demand for platinum remained very low during most of 2020 because of the worldwide shutdown (Khan and Derindere Köseoğlu, 2020).

2.4.1.4 Palladium

The substantial increase that can be seen in Figure 2.1 for palladium prices in the UK and Australia. The primary reason for this sudden shift was a significant increase in the demand for palladium-based catalysts, which drove up the price of palladium in the year 2000 and in the early months of 2001 to an all-time high. This in turn, led to the substitution of platinum-based catalysts, which had correspondingly significant technical implications. (Hageluken, 2006).

Since2008, the price of palladium has been on an unrelenting ascent, which may be attributed to a variety of factors; palladium are only extracted from the ground in a few of nations around the globe, many of them have not experienced political stability. There are just a few of applications driving demand, with catalytic converters for automobiles being one of the most important ones. In addition, issues such as politics, legislation, and technology, in addition to impacts on currency rates, can all have a significant part in the outcome. Speculative impacts are also a direct result of the lack of clarity around Russian regulations, stockpiles, and real shipments.

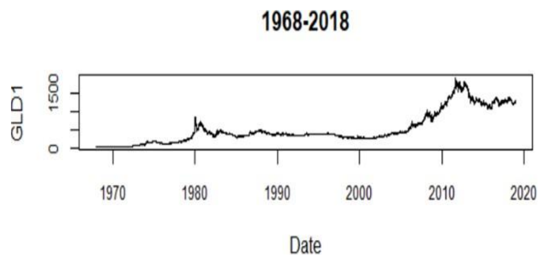
Overall, the prices of precious metals are relatively stable until around 2005. The demand for these precious metals started to grow from 2005 to 2012 for both developed and emerging markets. Similarly, for returns, all display high volatility in the early 1980s in developed markets, followed by a long period of relative stability. The period from 2005 shows the timing of global financial crises that hit in 2007, was the worst financial and economic disaster in the US (US housing bubble, commodities boom, and the Global Financial Crisis) and many major countries (Charles et al., 2015). Many individuals and institutions depend on day-to-day activities such as banks, pension providers, and insurance companies. Therefore, when the crisis hits globally, the after-effects can be felt for many years, as shown in Figure 2.1.

Precious metals prices witnessed a spike again from 2012 (see Figure 2.1) across developed and emerging economies. This considerable surge can be attributed to the panicked buying of gold bars and coins by small investors in Germany and Switzerland and the growing demand for gold jewelry from India's and China's burgeoning middle classes (Taskinsoy, 2022).

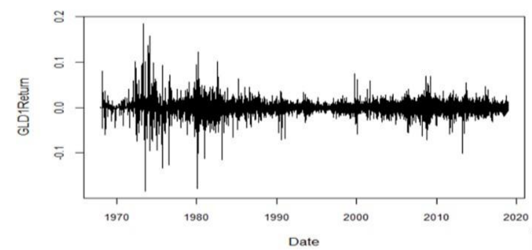
As discussed in chapter 1, business cycles and financial cycles have varying durations. Business cycles tend to be shorter much more influenced by events within and across economies, such as climatic, energy changes, and behavioral expectations of investors. The findings reported in figures 2.1-2.17 suggest there are mini cycles induced by business as well as financial crisis and other shocks such as housing bubbles, commodities booms and busts. The in depth analysis of graphs also do not support the longer cycle association with fluctuations in precious metals prices.

Figure 2.1: Gold, Silver, Platinum, and Palladium (Prices and Log Returns)

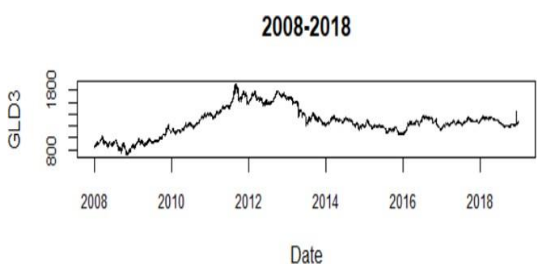
Gold UK (Price)



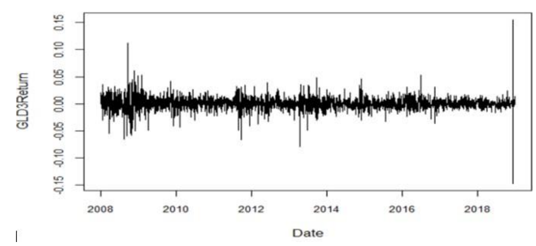
Gold UK (Log Return)



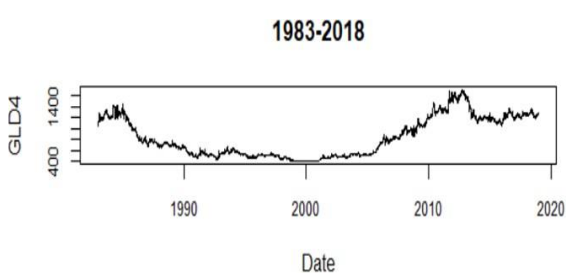
Gold Australia (Price)



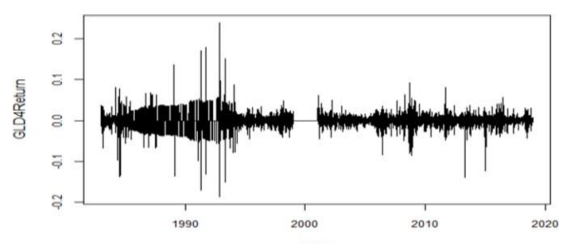
Gold Australia (Log Return)



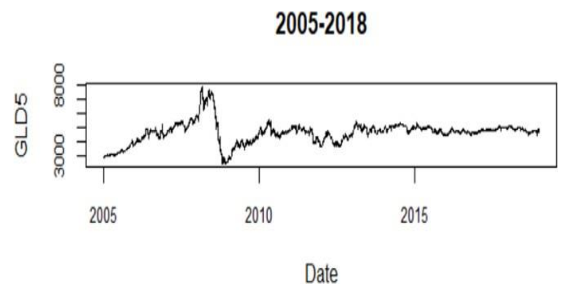
Gold Switzerland (Price)



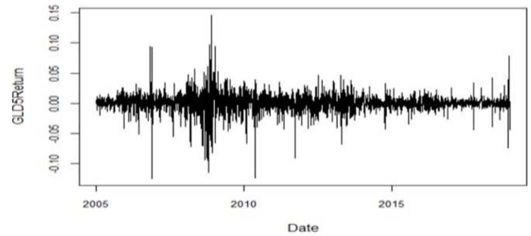
Gold Switzerland (Log Return)



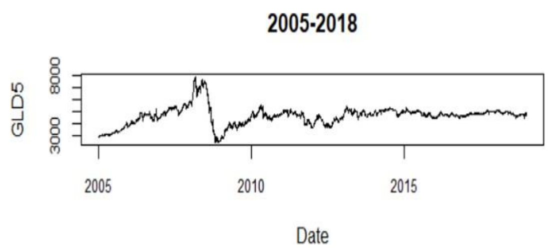
Gold Japan (Price)



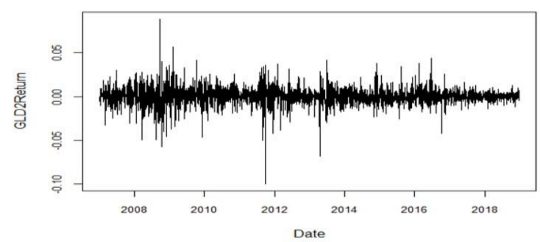
Gold Japan (Log Return)



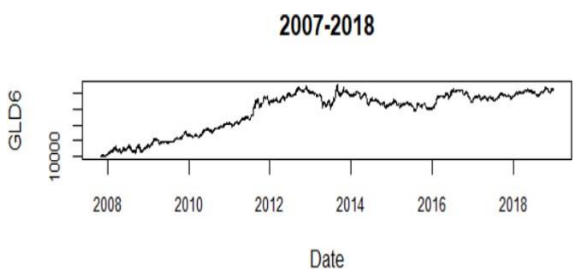
Gold China (Price)



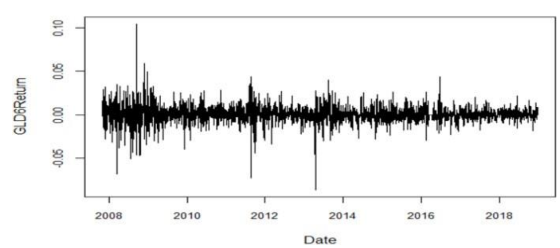
Gold China (Log Return)



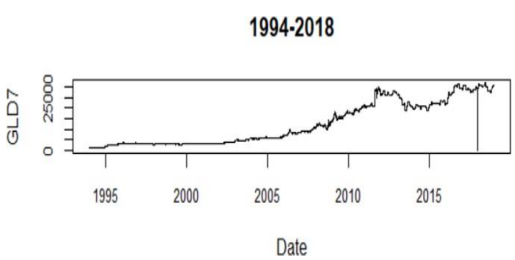
Gold India (Price)



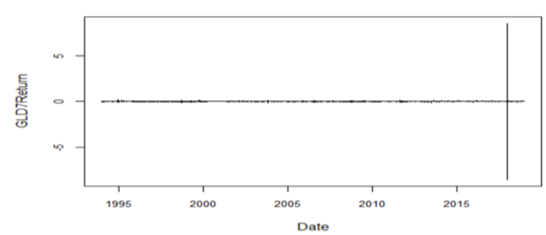
Gold India (Log Return)



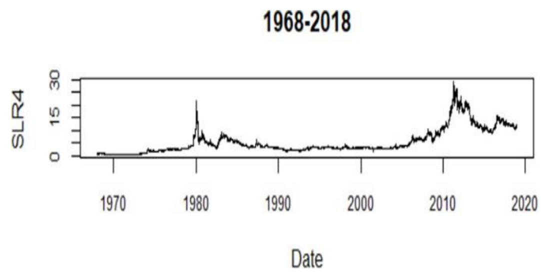
Gold Mexico (Price)



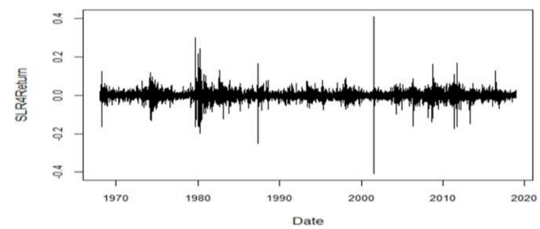
Gold Mexico (Log Return)



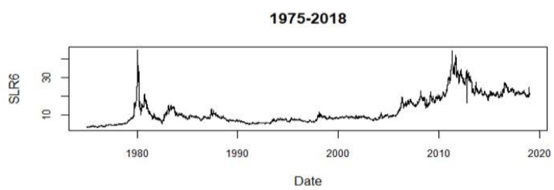
Silver UK (Price)



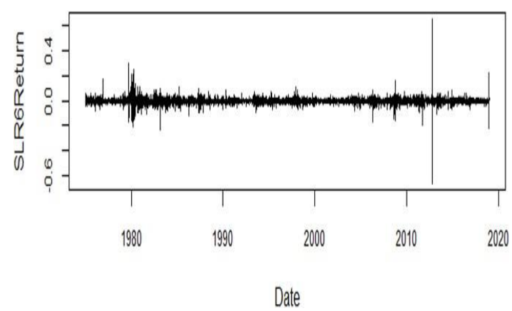
Silver UK (Log Return)



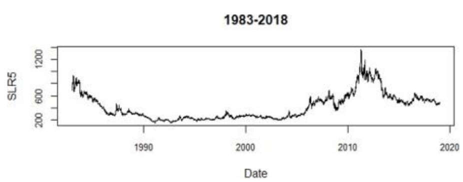
Silver Australia (Price)



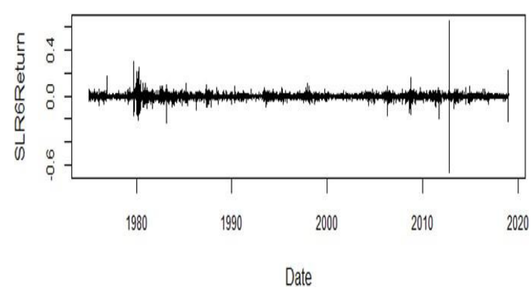
Silver Australia (Log Return)



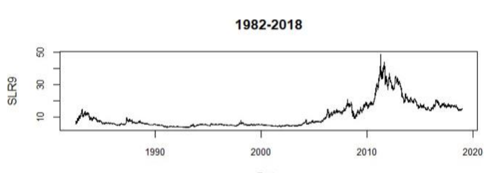
Silver Switzerland (Price)



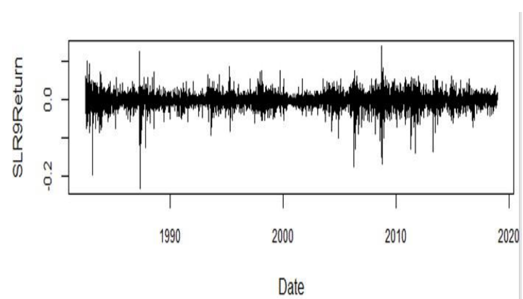
Silver Switzerland (Log Return)



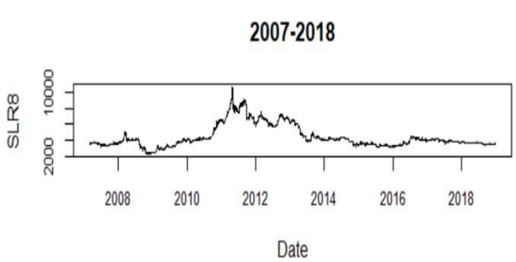
Silver USA (Price)



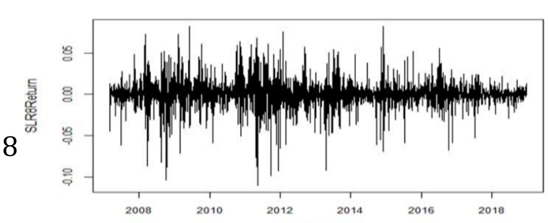
Silver USA (Log Return)



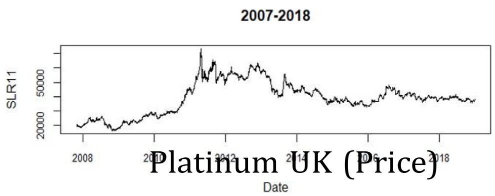
Silver China (Price)



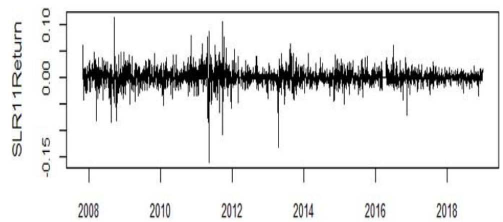
Silver China (Log Return)



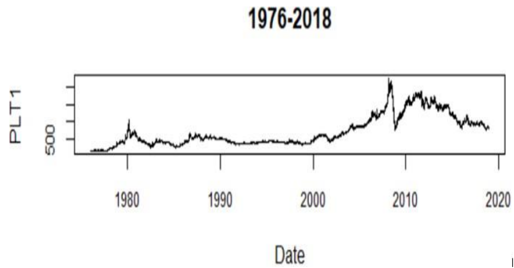
Silver India (Price)

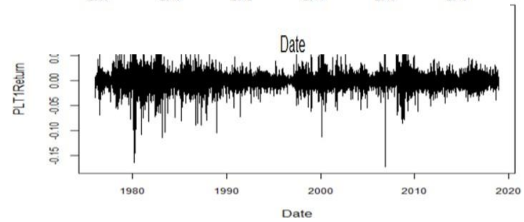


Silver India (Log Return)

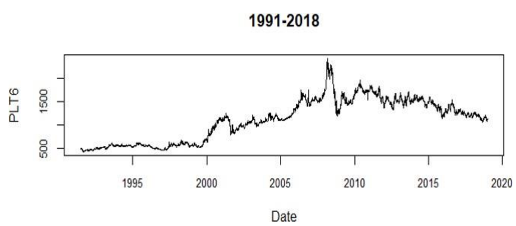


Platinum UK (Price)

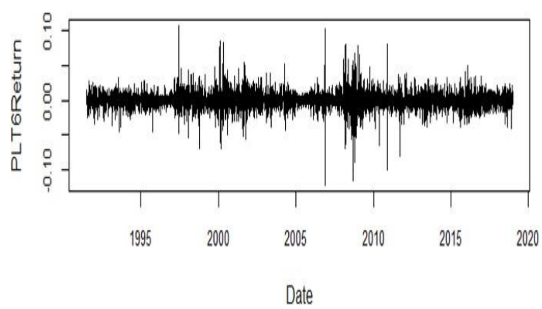




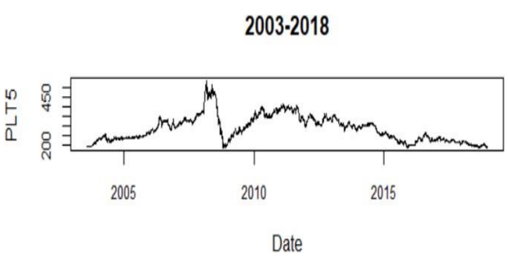
Platinum Australia (Price)



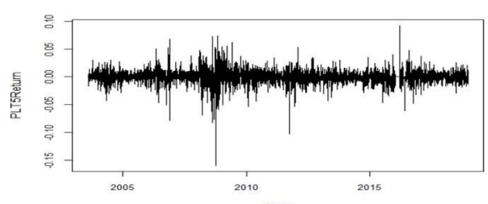
Platinum Australia (Log Return)



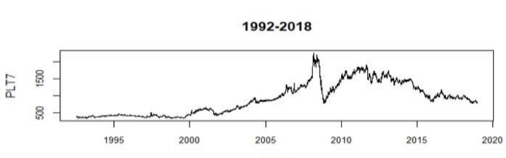
Platinum China (Price)



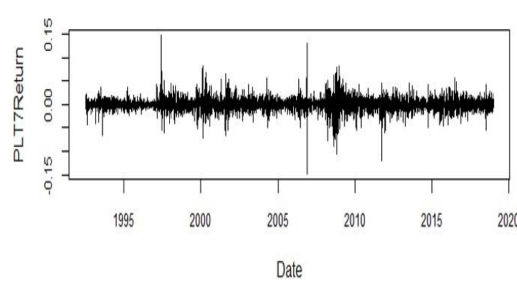
Platinum China (Log Return)



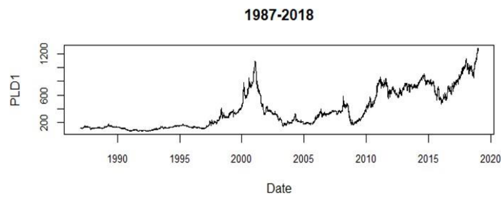
Platinum Hong Kong (Price)



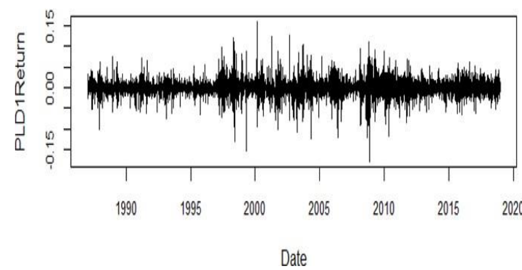
Platinum Hong Kong (Log Return)



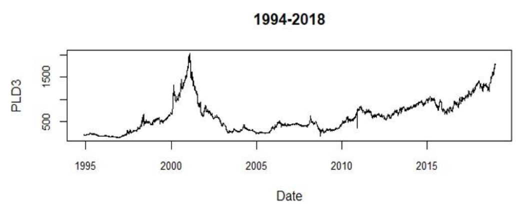
Palladium UK (Price)



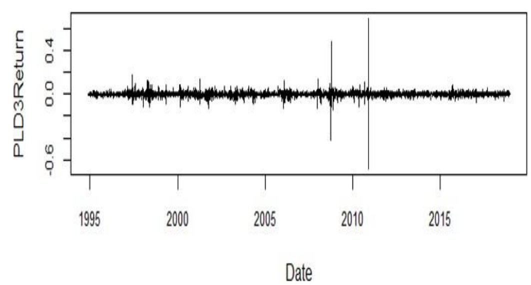
Palladium UK (Log Return)



Palladium Australia (Price)



Palladium Australia (Log Return)



2.4.2 Evaluating time-varying return predictability

The macroeconomic environment, government policies, world events, and often change in monetary policies inform the precious metals market volatility. It is validated from the test findings, as reported in figures 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8, and 2.9. 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 2.4.2 and provide analysis to determine whether precious metals markets are efficient (Ho) across developed and emerging markets. Although the starting point differs, the data set for 2005 - 2018 is available for all markets as depicted in the graphs figure 2.1- 2.17, the focus of our analysis is from 2005 - 2018. 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) reveals 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 5% asymptotic critical value of 3.84. Thus, if the AQ value is higher than the critical value, we reject the null hypothesis, the martingale difference hypothesis (MDH).

The second method we use an Automatic Variance Ratio test (AVR) as a way of measuring the weak form of efficiency of metal markets and assessing 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. However, it is reported that the small sample properties of the AVR test are entirely unknown when the return is conditional heteroskedastic. Hence, it is found that the AVR test is considered wild bootstrapped for the right size in small samples. The wild bootstrap test is desirable for small samples compared to its competitors i.e., the wild bootstrap variant of the Chow–Denning test Kim (2006) and the power-transformed joint test of Chen and Deo (2006).

Figure 2.10, 2.11, 2.12 and 2.13 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.

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 2.2 till 2.13. It means that precious metal markets frequently display a departure from market efficiency from time to time that reflects the implications of the AMH. However, the gold market has a long period of no-return predictability across developed and emerging markets since 2000 - 2018. For UK and Switzerland gold market, both tests AQ and AVR reject the MDH for 1982 and 2019, as shown in figure 2.2. The timing is in line with the US'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 2018 that shows the departure from market efficiency, as shown in figures 2.2, 2.6 and 2.10. 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 2.2, 2.6 and 2.10. The Global Financial Crisis (GFC) followed 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. Besides, 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).

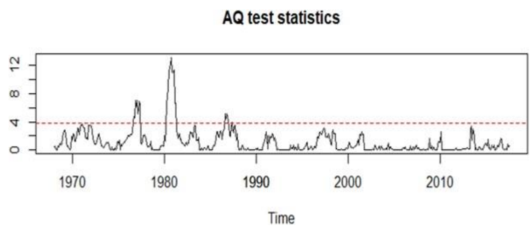
The data of silver for Japan and Mexico is not available, thus these countries are excluded from our study. Silver, platinum, and palladium markets have become most efficient since 2005 across developed and emerging markets. The AQ and AVR tests reject the MDH on the developed markets mainly in the UK and Australia in the period 1978–1979 as seen in figures 2.2, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8 and 2.9 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 efficient from 2005, as shown in figure 2.4, 2.5, 2.8 and 2.9. Our results validate the findings of Ismail and Abdullah (2013), who reported 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 & 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).

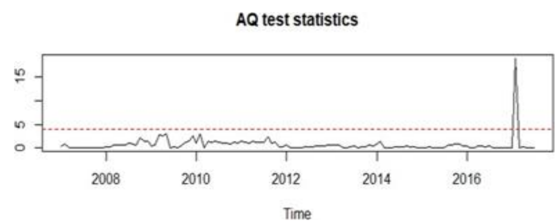
We also use the generalized spectral test (GS) to test the weak-form efficiency in precious metals across developed and emerging markets. As stated earlier, in section 2.4, the AQ and AVR tests are based on autocorrelation, which can only detect linear dependence. Therefore, Escanciano and Velasco (2006) 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, than it means that the test is significant. In this study, we used three tests adopted by Kim et al. (2011) in their study on the US market, which demonstrates a balanced combination of various statistical properties. The first test AQ is asymptotic, while the AVR and GS tests are small sample tests based on wild bootstrapping. Figure 2.14, 2.15, 2.16 and 2.17 displays 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 2.2: Gold Automatic Q Test

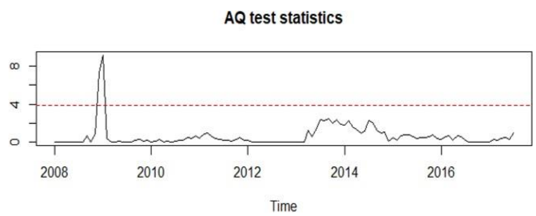
Gold UK



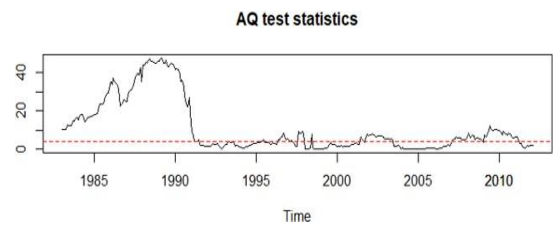
Gold China



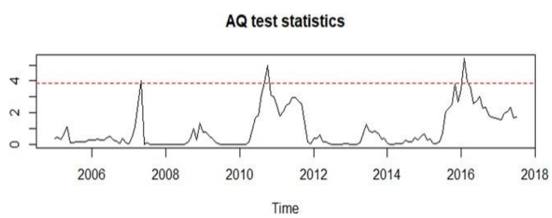
Gold Australia



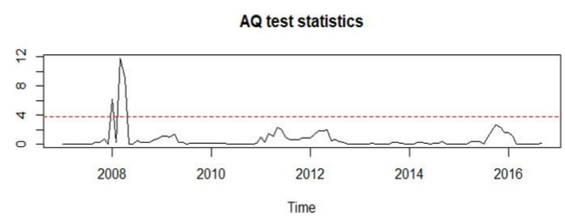
Gold Switzerland



Gold Japan



Gold India



Gold Mexico

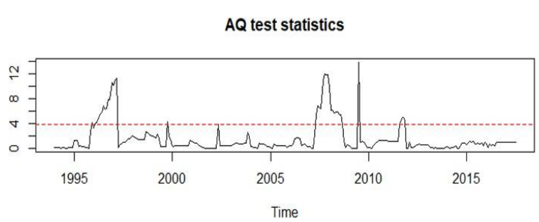
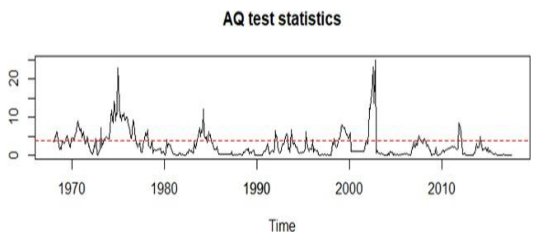
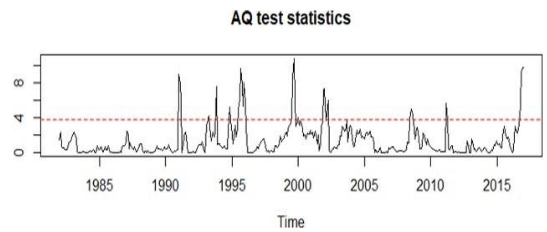


Figure 2.3: Silver Automatic Q Test

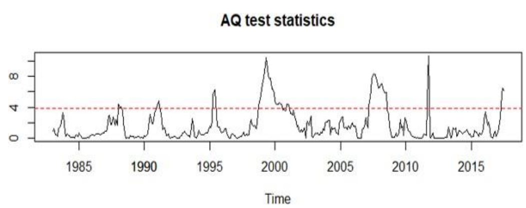
Silver UK



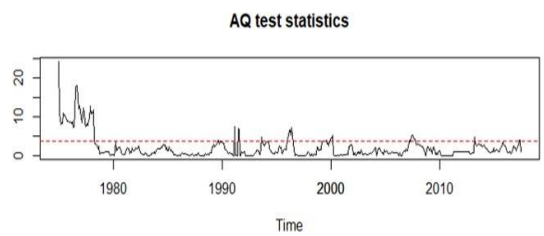
Silver USA



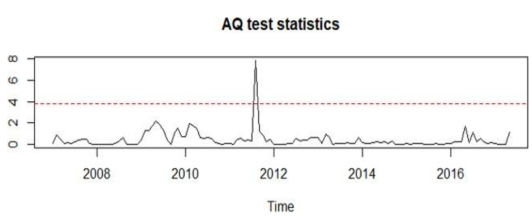
Silver Switzerland



Silver Australia



Silver China



Silver India

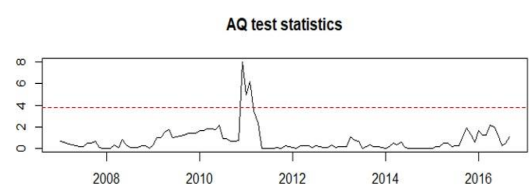
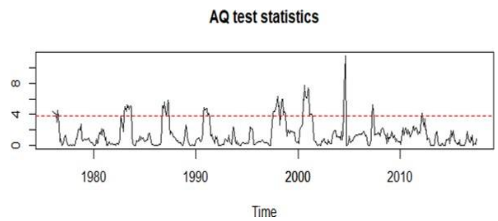
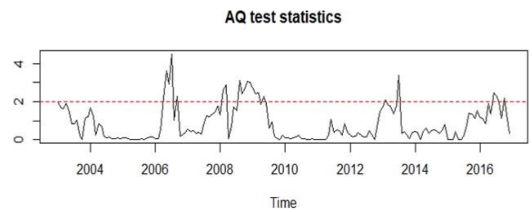


Figure 2.4: Platinum Automatic Q Test

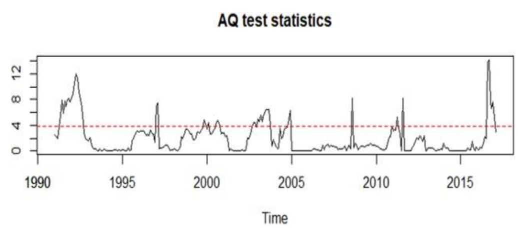
Platinum UK



Platinum China



Platinum Australia



Platinum Hong Kong

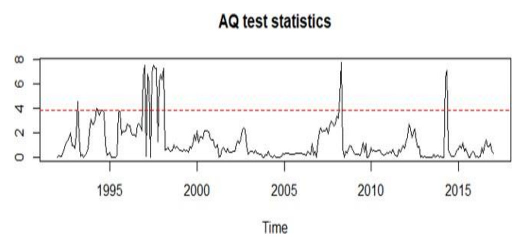
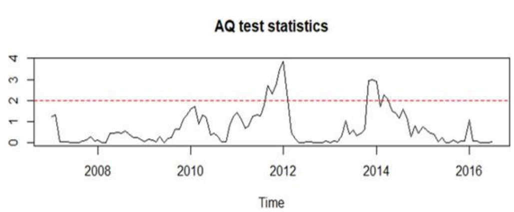


Figure 2.5: Palladium Automatic Q Test

Palladium UK



Palladium Australia

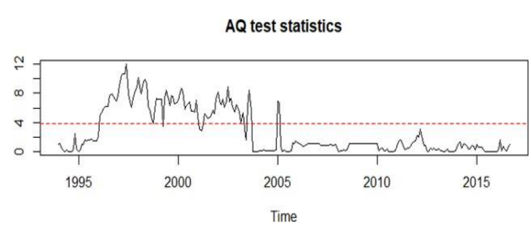
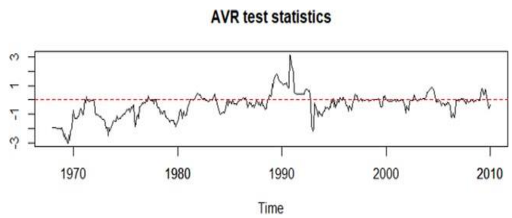
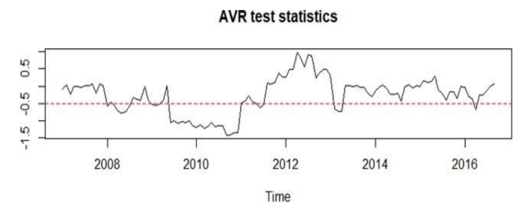


Figure 2.6: Gold Automatic Variance Ratio Test

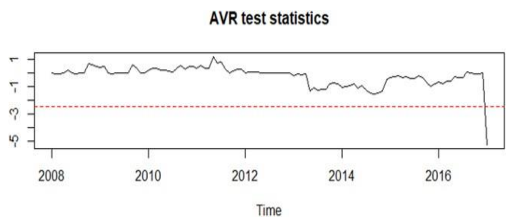
Gold UK



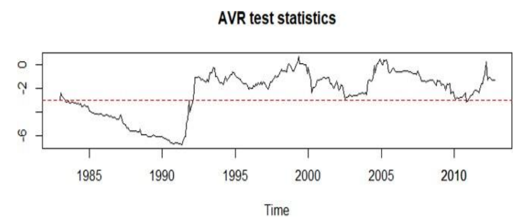
Gold China



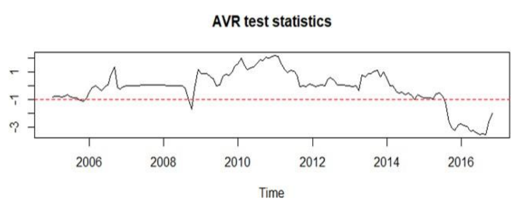
Gold Australia



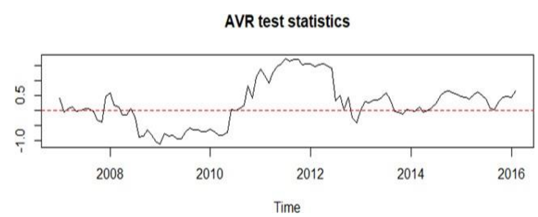
Gold Switzerland



Gold Japan



Gold India



Gold Mexico

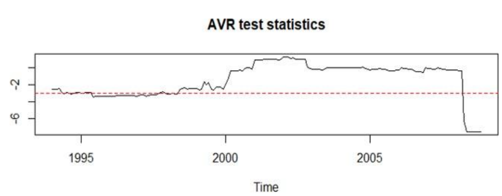
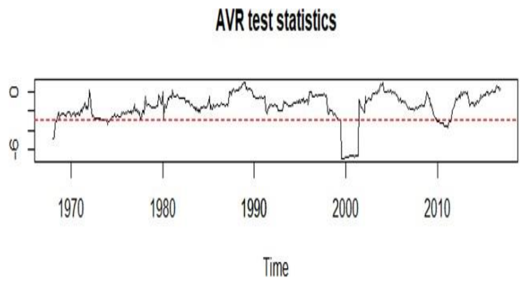
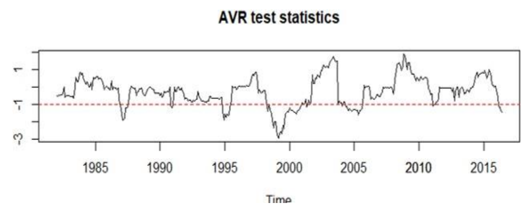


Figure 2.7: Silver Automatic Variance Ratio Test

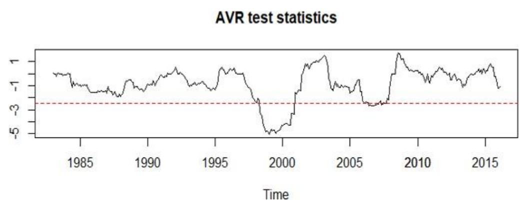
Silver UK



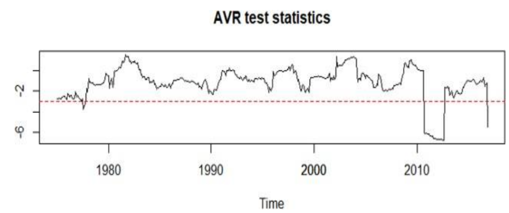
Silver USA



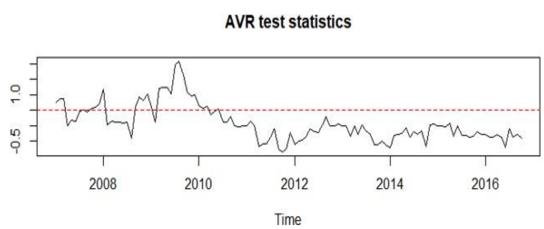
Silver Switzerland



Silver Australia



Silver China



Silver India

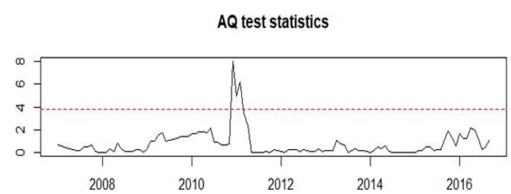
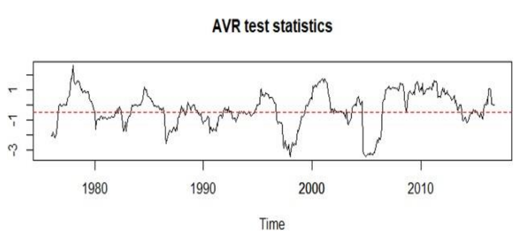
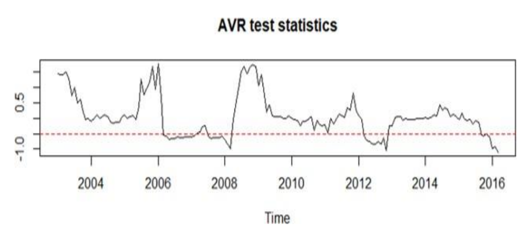


Figure 2.8: Platinum Automatic Variance Ratio Test

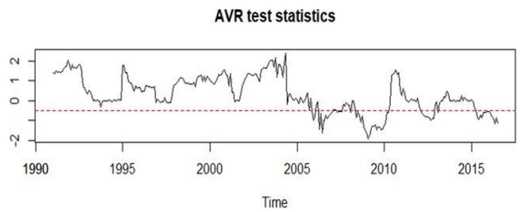
Platinum UK



Platinum China



Platinum Australia



Platinum Hongkong

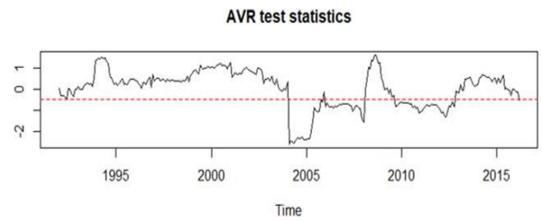
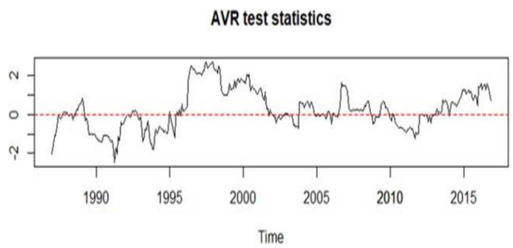


Figure 2.9: Palladium Automatic Variance Ratio Test

Palladium UK



Palladium Australia

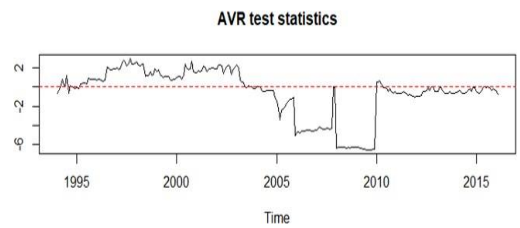
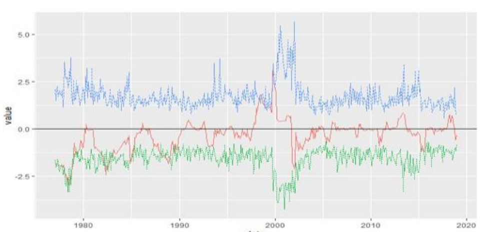


Figure 2.10: Gold Autoboot Variance Ratio Test

Gold UK

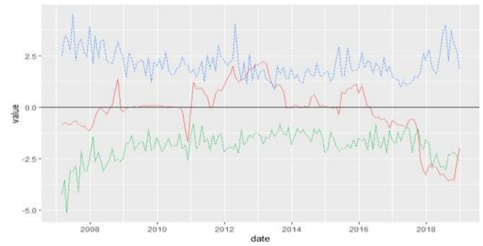


Gold China

Gold Australia

Gold Switzerland

Gold Japan



Gold India

Gold Mexico

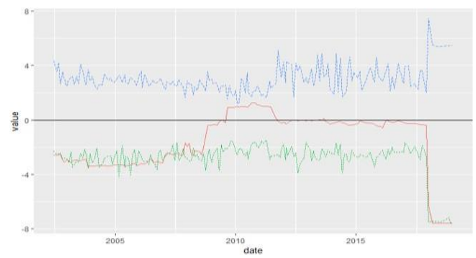
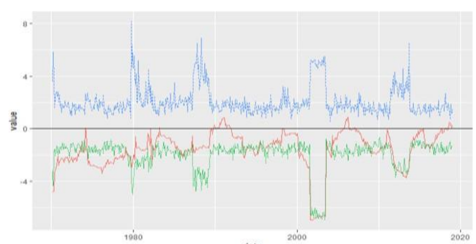


Figure 2.11: Silver Autoboot Variance Ratio Test

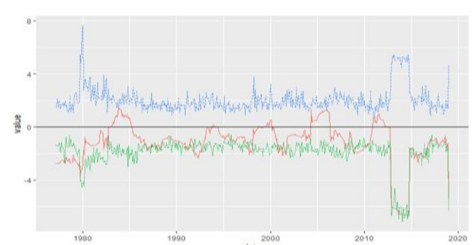
Silver UK



Silver USA

Silver Switzerland

Silver Australia



Silver China

Silver India

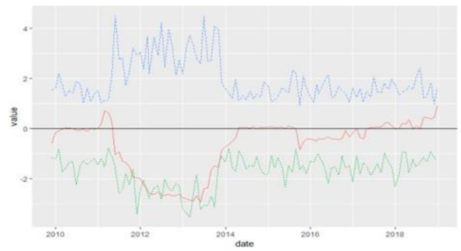
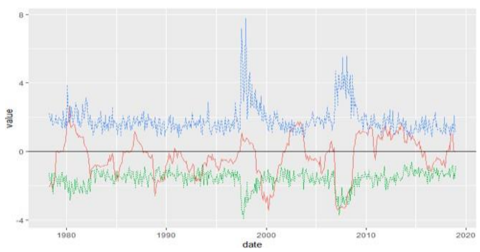
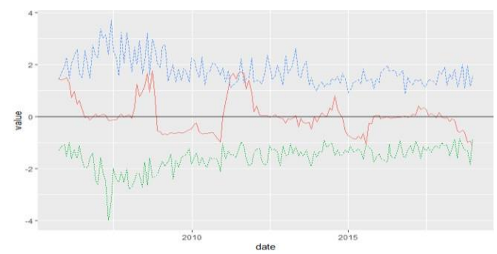


Figure 2.12: Platinum Autoboot Variance Ratio Test

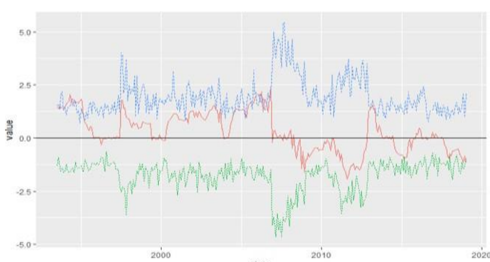
Platinum UK



Platinum China



Platinum Australia



Platinum Hongkong

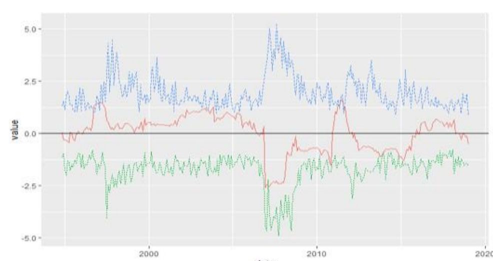


Figure 2.13: Palladium Autoboot Variance Ratio Test

Palladium UK

Palladium Australia

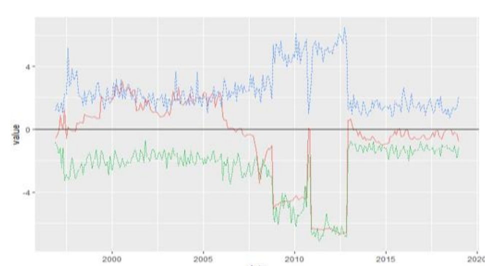
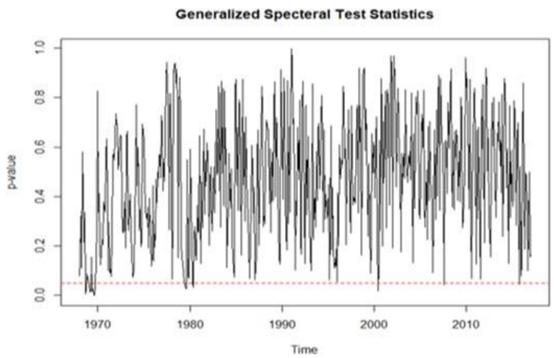
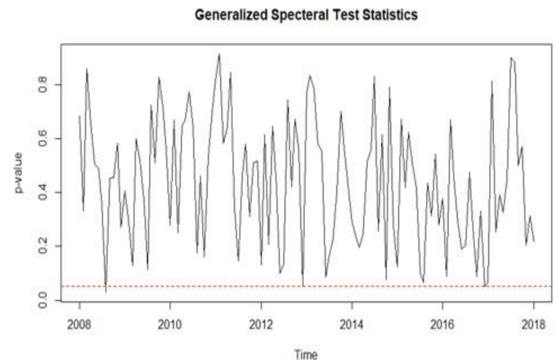


Figure 2.14: Gold Generalized Spectral Test

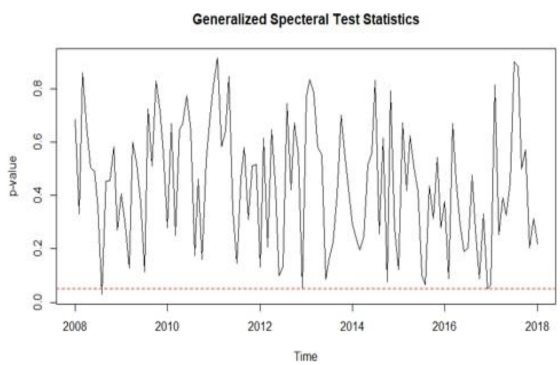
Gold UK



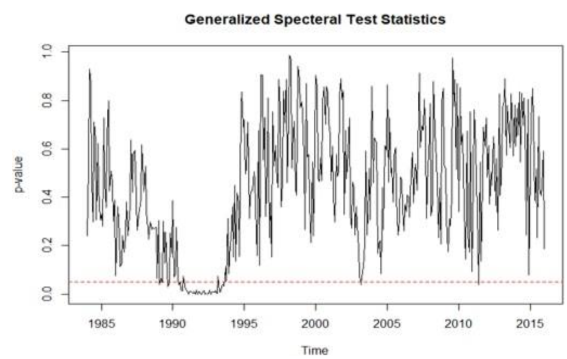
Gold China



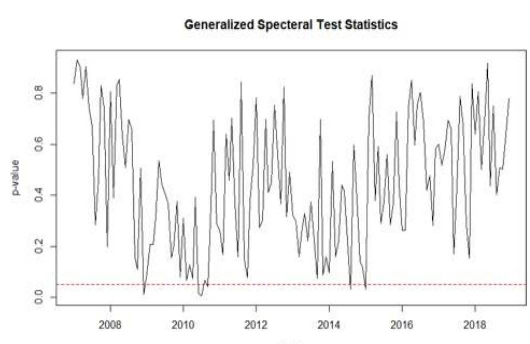
Gold Australia



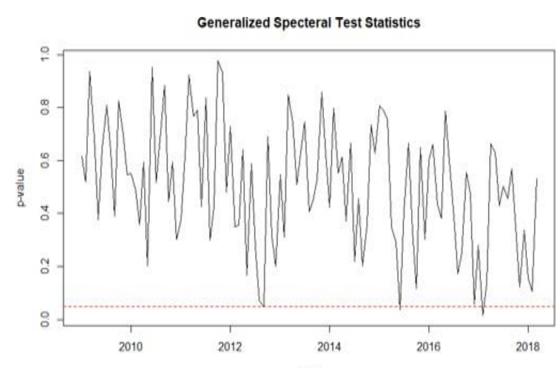
Gold Switzerland



Gold Japan



Gold India



Gold Mexico

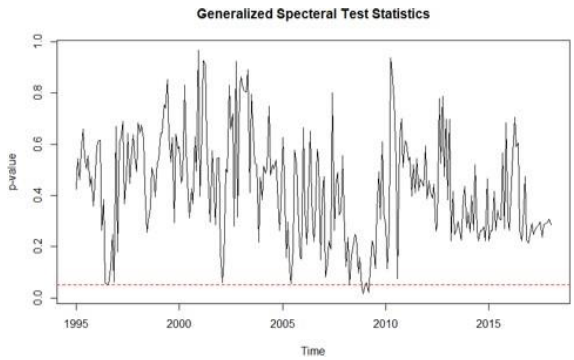
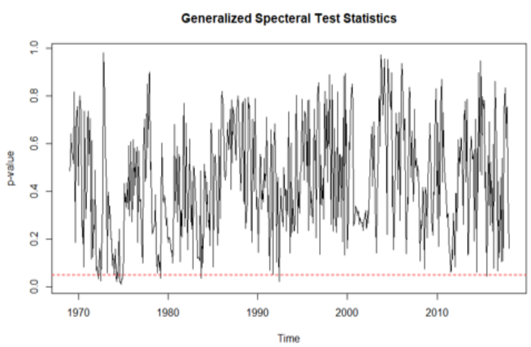
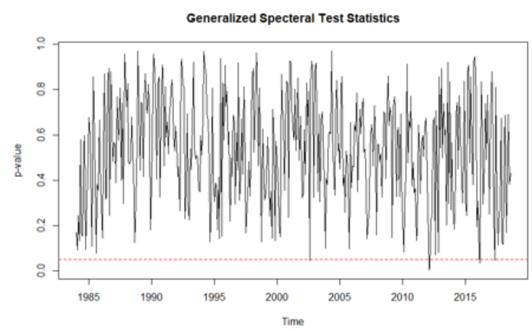


Figure 2.15: Silver Generalized Spectral Test

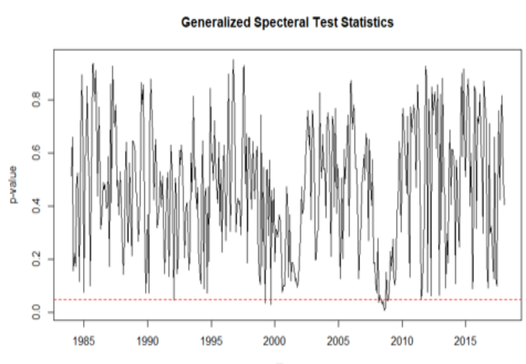
Silver UK



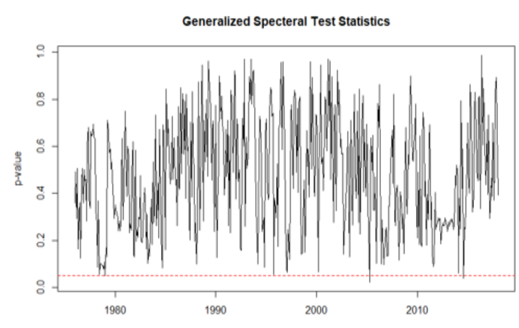
Silver USA



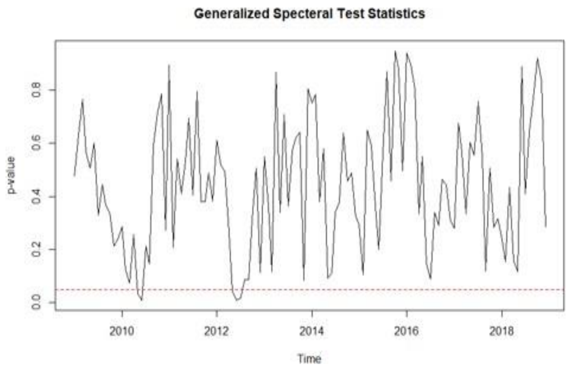
Silver Switzerland



Silver Australia



Silver China



Silver India

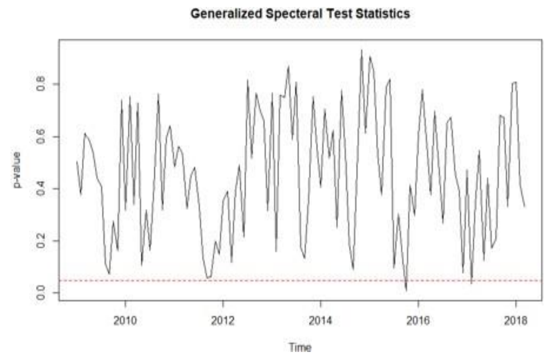
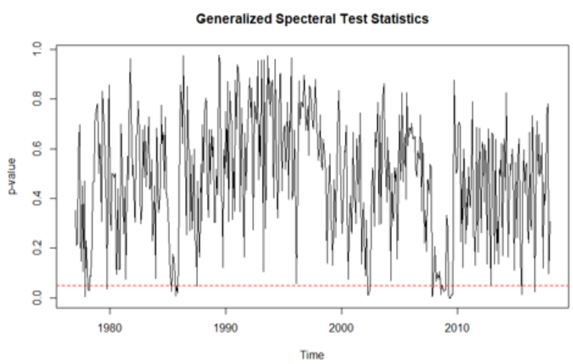
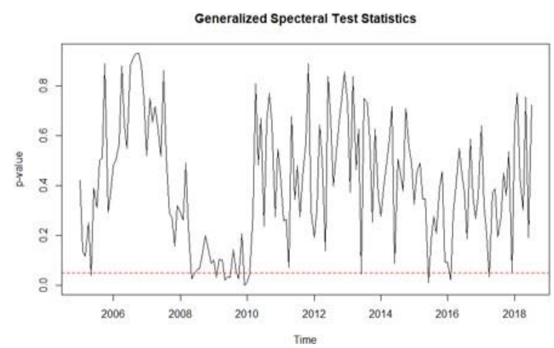


Figure 2.16: Platinum Generalized Spectral Test

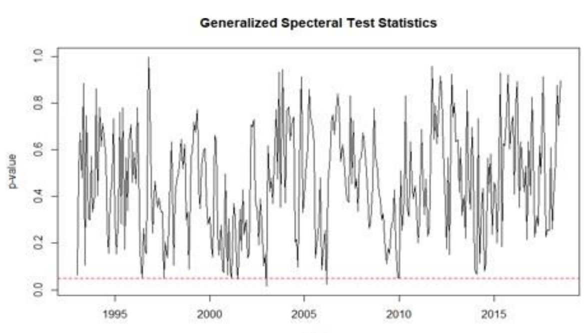
Platinum UK



Platinum China



Platinum Australia



Platinum Hong Kong

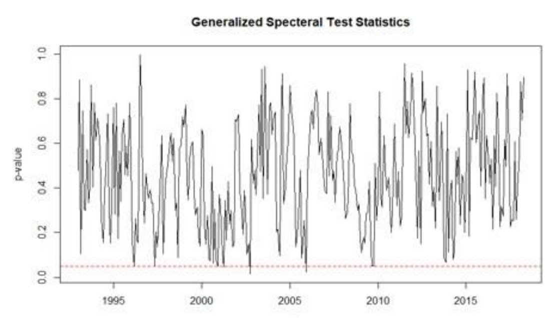
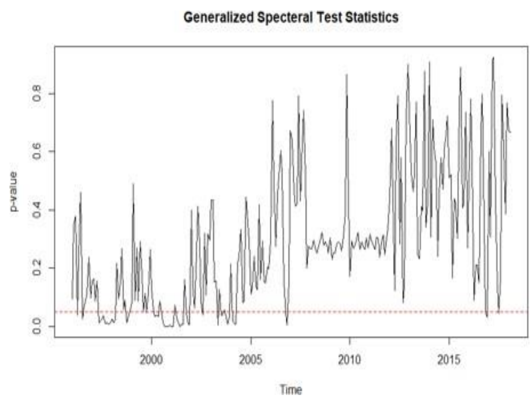
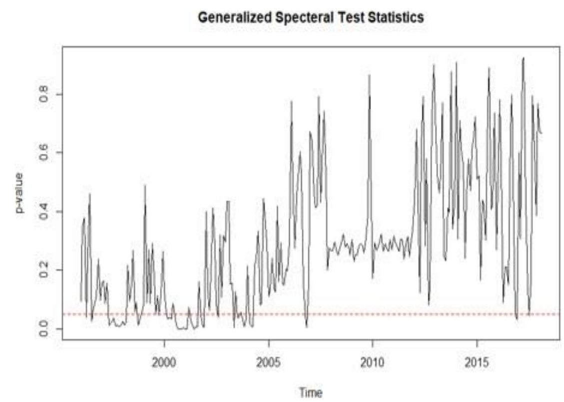


Figure 2.17: Palladium Generalized Spectral Test

Palladium UK



Palladium Australia



2.5 Conclusion

Precious metals are a core component of an investment portfolio, mainly in view of their assets treated as a safe haven by investors and institutions. Whilst purchasing the commodities, many investors and traders wondered if these essential commodities are efficiently priced, as it is a primary feature of their time allocations. This paper examines the weak-form efficiency of four precious metal (gold, silver, platinum and palladium) across developed and emerging markets. To analyze this, we use the innovative methods, Autocorrelation-based and Spectrum-based MDH experiments, namely: (i) Automatic Portmanteau Test (AQ), (ii) Automatic Variance Ratio Test (AVR), and (iii) Generalized Spectral Test. The generalized spectral test was conducted to identify potential nonlinear dependency in metals returns.

Our analysis indicates that the time predictability for the four metals markets differs throughout the duration. The degree of predictability of returns depends on the macroeconomic environment, government policies, world events, change in monetary policies, and prevailing political and economic conditions. We find evidence that the precious metals markets also show a departure from market efficiency from time to time that illustrates AMH's implications. The precious metals return predictability and volatility are observed differently from normal conditions, especially during the market unrest and bubble times for reasons. There are several reasons for the movement capital from capital markets; this may be explained for technical, economical and speculative strategies used by investors to exploit perceived or real market imperfections.

However, in well-functioning economies, the difference between predicted and actual market returns cannot be consistently exploited as the evidence suggests it is impossible to predict future direction or events. The findings of this study suggest market efficiency for four precious metals varies over time across developed and emerging markets. The variation for market efficiency could be attributable to cyclical movements in economies due to technological events and business boom or burst. Be- sides, other psychological and macroeconomic conditions could impact the volatility of precious metals prices. However, such latent factors are not necessarily captured by data used to forecast price movements.

The findings of this study have implications for individual investors and institutions when selecting precious metal for inclusion in their portfolios to diversify their risk. The metals variability in price is inversely related with macroeconomic environment within country of trade, production, and the industrial use of the metals. Therefore, it is imperative to examine characteristics of precious metals, market efficiency and the benefit of their inclusion to hedge portfolio risk. This study suggests precious metals price movements; there is a need to incorporate soft non-quantitative factors when evaluating precious metals price movements.

3 Chapter 3: Impact of Macroeconomic Factors on Precious Metals Prices: Evidence from Specific Developed and Emerging Economies (Paper 2)

Abstract

This study examines the relationship between macroeconomic factors and precious metals prices across developed and emerging markets from 1979 to 2020 using the multiple time series techniques - Johansen cointegration test, VECM, VAR, ARDL model, and Wald test. The changes in the price of precious metals are useful indicator of the economy's health since these metals have historically served as a good hedge against inflation and are therefore highly valuable. The findings revealed patterns that change depending on where you are on the world. The long run cointegrating relationships are unstable and vary significantly between developed and emerging economies, revealing multiple structural breaks in the cointegrating relationships between precious metals and inflation, financial crises, and recession periods. The causality test results between four precious metals and major macroeconomic indicators differ, depending on the country and length of the frequency distributions used. This study provides policy inputs, aids investors and hedgers who seek to invest in various markets by developing strategies and diversifying their portfolios based on different frequency distributions and provide policy inputs to the government.

Keywords: Precious Metals prices, Long-run Equilibrium, Inflation, Financial Crises.

3.1 Introduction.

Precious metals are considered as secure forms of investment relative to equities and bonds, especially at times of uncertainty (Hillier et al., 2006, Baur and McDermott, 2010, Lucey and Li, 2015). Evidence from several studies suggest precious metals prices are resilient during economic downturns and vice versa. In addition, almost 80% of precious metals were exported by China to US. However, China increased the use of precious metals domestically that lessoned the export to US. This emerged as a central issue in the ongoing trade conflict between the United States and China between 2014 and 2017 (Baur and McDermott, 2010, Ciner et al., 2013, Agyei-Ampomah et al., 2014, Lucey and Li, 2015, Batten et al., 2015). This lead to fundamental changes in the dynamics of precious metals markets which also impacted on supply and demand resulting in price volatility, something that has become subject of studies by academics (Figuerola-Ferretti and McCrorie, 2016, Klein, 2017).

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 (Erb and Harvey, 2006; Gorton and Rouwenhorst, 2006; Roache and Rossi, 2010). As a result, the volatility spillages of precious and industrial metals may be expected to demonstrate distinctive features, particularly during certain periods (e.g., the 2008 global financial crisis). However, the two metal groups share several characteristics that prevent them from being considered entirely distinct. Precious metals are used in various products, such as electronic and communication equipment, spacecraft and jet aircraft engines, mobile phones, and catalytic converters. Gold, silver, platinum group metals, and palladium are most recovered because they are found in electronics, X-ray films, photographic emulsions, industrial applications (catalysts, batteries, glass/mirrors), and jewellery (Canda et al., 2016).

This study examines the long run cointegrating relationship between major macroeconomic factors and precious metals prices for each economy across developed and emerging economies from 1979 to 2020. The purpose of evaluating individual country level analysis, using appropriate techniques, is to investigate how macroeconomic factors affect precious metals prices in different economies and how the investors respond to changes in macroeconomic events when managing or developing their portfolios to mitigate risk. Moreover, each country selected for this study have different economic and market environment that affect macroeconomic factors differently. Therefore, to study how precious metals prices are affected in each country in relation with macroeconomic factors. It was considered necessary to undertake individual country analysis. The study examines short and long run relationship between between prices of 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).

Precious metals markets are highly unpredictable and hard to anticipate because of their unique characteristics and intrinsic value. This requires complex and appropriate modelling to study volatility and correlation dynamics which are essential in precious metal markets. Numerous studies find that commodity and precious metals markets volatility and correlation are linked to macroeconomic activity as well as supply and demand dynamics (Anson, 2008, Belousova and Dorfleitner, 2012). It is suggested that investors and portfolio managers can make better investment decisions, if they have a more accurate picture of precious metals market characteristics, including volatility and correlation (Dinh et al., 2022).

In this study, we adopt various time series techniques based on data availability and differences in market conditions. We considered the developments concerning the unit root properties revealed by Dickey and Fuller (1979) and Phillips and Perron

(1988) to test breaks exogenously by taking the series' unknown break dates. In this study, we applied both linear and nonlinear testing procedures to identify the relationship between variables under study. There are numerous cointegration techniques in the economic literature. According to Nkoro et al. (2016), the econometric term "cointegration" refers to the existence of a long-run equilibrium between economic variables that con- verges over time. The examples of cointegration techniques include those proposed by Engle and Granger (1987), Johansen (1988), Johansen and Juselius (1990), Saikkonen and Lütkepohl (2000) and Pesaran et al. (2001).

Moreover, we use the Autoregressive Distributed Lag (ARDL) and Johansen and Juselius (JJ) cointegration techniques to confirm a long-run relationship between four precious metal prices and the six key macroeconomic factors in developed and emerging economies. The ARDL approach is considered the most recent cointegration technique for examining dynamic and equilibrium relationships between economic variables. Monthly closing prices of four precious metals and the CPI, IP, SP, LIR, SIR, and UR were used from January 1979 to September 2020, with 501 maximum and 85 minimum monthly time series observations due to the absence of data for several nations prior to and after the sample period.

Over the last few years, a substantial amount of research has been published on the relationship between precious metals (Gold, Silver, Platinum and Palladium) and inflation; however, the findings and conclusions are inconsistent (O'Connor et al., 2015; Vigne et al., 2017). In comparison to the bulk of research on the relation- ship 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 aims to provide a better understanding of which macroeconomic factors have the most significant impact on the pricing of precious metals across developed and emerging economies. Furthermore, compared to previous studies, this study provides broader international coverage, whereas most of the literature tended to concentrate on a single economy, mainly developed economies. Moreover, the findings of this study assist investors and hedgers to design hedging strategies to invest in multiple markets and diversify their portfolios based on distinct frequency distributions.

A prudent investor cannot ignore inflation when constructing a portfolio as inflation is inextricably linked to buyers' purchasing power and has a significant impact on the behaviour of commodity investors (Delatte and Lopez, 2013). Hence, it is imperative 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.

In light of the above findings on the relationship of precious metals and macroeconomic factors, this study considers almost 50 years of data and the data span from 1971 - 2020. However, the data range differs across developed and emerging economies and relies on linear and non-linear cointegration analyses to understand when and why macroeconomic factors impact precious metals prices.

The remainder of the study is structured as follows; Section 2 discusses the history of precious metals and their relationship to macroeconomic determinants. Section- 3 describes the methodology in detail. However, Section-4 explained the empirical results. Section-5 is the conclusion.

3.2 Literature Review

There is a considerable impact of macroeconomic factors on the prices of different metals and their trading activities. Tan and Ma (2017) reported in their research that macroeconomic uncertainty shocks have impacted the returns of commodity prices. Most of the time, this trend exists in those states where uncertainty is high compared with low-uncertainty states. Moreover, they confirmed that precious metals investment is a safe haven for the investor both in the short-run and long-run. Due to the high volatility of financial markets, adequate portfolio diversification is required to mitigate risk. Investors generally seek investment opportunities with reasonable average returns and a negative correlation to the stock market. As a result, it is critical to understand better the long-term relationships between the financial assets in a portfolio to minimise overall risk and maximise returns (Froot, 1995).

Mensi et al. (2015) investigated the dynamic relationships between strategic commodity futures markets, including West Texas Intermediate (WTI) oil, gold, silver, wheat, corn, rice, and the Saudi stock exchange. They found that the presence of commodities in portfolios based on the Saudi market is helpful for investors. To design strategies for optimum asset allocation, portfolio optimisation, reduced downside risk, and hedging, good modeling of time-limited relations between the commodity and equity markets is required in the first instance. Therefore, combining investment in commodities with low or negative relationships with equity properties should offer better diversification than a commodity-free portfolio. A mixed stock portfolio can therefore deliver more expected returns and low risk than an inventory-only portfolio. Batten et al. (2010) examined four precious metals' (gold, silver, platinum, and palladium) monthly price volatilities and found an impact of macroeconomic factors such as business cycle, economic environment, and financial market sentiment on precious metals pricing fluctuation. Yin and Han (2016) reported that there is a significant impact of macroeconomic factors on commodity markets in China, whereas US macroeconomic factors have more impact on the commodity market than China in terms of the size of coefficients their level of significance.

3.2.1 Inflation and Precious Metals

Precious metals have been considered an effective anti-inflation hedge than fiat currencies, owing to their inherently limited production (Vigne et al., 2017). 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 BC has motivated research in this sector (Hall et al., 2011). Financial protection has been approached from various perspectives, and some questions have been addressed more comprehensively than others by Baur and McDermott (2010) and Baur and McDermott (2010).

Gold is a beneficial investment during times of market volatility, particularly in developed and emerging countries, as evidenced by Baur and McDermott (2010). There has been observed a rise in the number of academic and professional researchers studying the nature and role of gold in financial markets followed with the abandonment of the Bretton Woods System in 1971 and the conversion of the United States to a fiat currency. However, gold's ability to act as a financial protector remains debatable (Lucey et al., 2017).

Many economists and monetary institutions confirmed that commodity prices have significant inflationary consequences (Gospodinov and Ng, 2013). Bruno and Chincarini (2010) demonstrated that gold is an essential commodity in a portfolio that outperforms inflation. Gold is the most traded asset and has the ability to outperform traditional assets in an inflationary scenario (Dempster and Artigas, 2010). Taylor (1998), Fama (1990) and Pearce and Roley (1988) have made efforts to empirically estimate the relation between asset prices and real economic activities in terms of production rates, productivity, gross product growth rate, unemployment, yield spread, interest rates, inflation and dividend yields. Jaffe (1989) examined the relationship between gold and inflation and suggested that gold is not a good inflation hedge, but these findings are limited due to the short time intervals within only 17 years.

Similarly, Jastram (2009) investigated the relationship between gold and inflation for the period of 1560 to 1976 and reported that gold does not effectively hedge commodity prices on a yearly basis as "gold does not match commodity prices in their cyclical swings." However, in the long run, he argued, gold maintains its purchasing power remarkably well due to the "Retrieval Phenomenon." which means that gold prices do not chase after commodities; commodity prices return to the index level of gold over and over. However, Kolluri (1981) revealed in his study that gold is a good hedge against inflation. Subsequently, Larsen and McQueen (1995) indicated that gold acted as a hedge against inflation, but gold stocks did not.

Taylor (1998) had interesting findings and concluded that gold was a hedge against inflation before World War II but only partially hedging abilities around the two 1970s oil crises. Batten et al. (2010) examined the long-run dynamic relationship between inflation and the price of gold and concluded that the gold–inflation relationship is highly time-dependent. Moreover, changes in interest rates significantly affect the relationship between gold and inflation, demonstrating gold's monetary nature as a commodity. Wang et al. (2011) investigated the short-run and long-run inflation hedging efficacy of gold in the United States and Japan from January 1971 to January 2010 and found that increases in gold prices reflect inflationary pressure.

Ranson and Wainwright (2005) found that gold provides the most robust protection against inflation, as evidenced in the US and UK economies throughout 1968 to 2005. Interestingly, their study concluded that gold prices rose four years in a row before a high inflationary period. Moreover, the gold price increase was 2 to 3 times higher after the increase than inflation and has effectively hedged inflation. Levin et al. (2006) applied cointegration regression methods on monthly data started from January 1976 - August 2005 to detect long-term and short-term gold price determinants in the US. Based on the empirical analysis, they found no significant relationship between changes in the price of gold and changes in world inflation. However, Blose (2010) used Consumer Price Index (CPI) and expected change in the CPI as an explanatory variable to analyse the effect of changes in expected inflation in terms of Consumer Price Index (CPI) on gold prices in the US economy. The monthly data used, spanning from March 1988 through February 2008, concluded that the gold prices do not change due to changes in expectations regarding future inflation.

Ozturk and Acikalin (2008) employed the Johansen cointegration techniques and the Granger causality test within a Vector Error Correction Model Framework (VECM) framework to test whether the gold has the characteristics of an internal hedge and/or an external hedge against Turkish Lira (TL). Ozturk and Acikalin also used the monthly data of CPI from January 1995 through November 2006 and cointegration test results confirmed the existence of long-term relationships between the gold price and consumer price index (CPI). Moreover, Ozturk and Acikalin concluded that gold acts as an effective hedge during high inflation in Turkey.

Similarly, Ghosh et al. (2004) also reported that the US Retail Price Index has an influence on the long-run relationship between gold and inflation. Conversely, Van Hoang et al. (2016) found that gold is never a hedge in the long-run, but it is in the short-run for the UK, the US and India. Besides, Beckmann and Czudaj (2013) findings suggested that gold partially hedges against inflation.

Adrangi et al. (2003) reported that the real gold returns protect against expected inflation but not against unexpected inflation. Blose (2010) investigated whether changes in expected inflation affect gold prices by using the sudden changes in the consumer price index, and the results indicate that surprises in the CPI do not affect gold spot prices. In addition, Feldstein (1980) suggested that an increase in expected inflation leads to an increase in the gold price. Artigas et al. (2010) also found that the price hike of gold predicts future inflation. Ranson and Wainright (2005) argued in their findings that gold is a better predictor of inflation than oil as it cannot be consumed.

Awokuse and Yang (2003) examined whether commodity prices provided helpful information for monetary policy formulation and discovered that commodity prices signal the economy's potential course. Bampinas and Panagiotidis (2015) investigated the long-run hedging ability of gold and silver prices against alternative consumer price index measures for the UK and the US. They reported that gold is an inflation hedge in the long run for both developed economies. The results of Hoang (2011) also supported the findings of Bampinas and Panagiotidis (2015). Sharma (2016) examined whether the consumer price index (CPI) predicts gold price returns using data from 54 countries and concluded that the CPI does predict gold price returns in the United Kingdom and the United States, among other countries.

Batten et al. (2014) analysed the long-term dynamic relationship between inflation and the price of gold. Batten et al. findings suggest that there is no cointegration relationship if the volatile period of the early 1980s is omitted from the data. Baur (2013) conducted a theoretical and econometric study of the fundamental factors of gold. Furthermore, the study found that inflation was a key driver of the gold price in the 1970s and between 2003 and 2013. Similarly, Chua and Woodward (1982) researched six major industrial countries from 1975 to 1980 to determine whether gold has been an effective hedge against inflation for investors. According to the findings, the US inflation rate has the most significant impact on the gold price.

Taylor (1998) examined the capacity of white precious metals to hedge against inflation using evidence from 1914 to 1996. The silver findings revealed a long-running hedge over the measured duration and a short-running hedge against the US CPI over several sub-periods of the study. A noteworthy observation is that silver was a hedge during the OPEC crisis of 1979, but not during the first OPEC crisis of1973. Silver has been a hedge. The findings of Johansen's collaboration with platinum and palladium show that the two white precious metals were used as a long-term inflation hedge, while evidence also points towards the short-run hedging abilities of platinum.

Adrangi et al. (2003) extended the investigation a few years later, using monthly estimates of London Fix silver prices between April 1967 and November1999, as well as the American Industrial Production Index (IP) and the Consumer Price Index. The findings showed that silver was a strong inflation shield over the considered period. Furthermore, the authors found that the Fischer (1930) hypothesis holds true, implying that real silver returns are not adversely affected by inflation.

In the past, gold was found as the most potent protection against inflation. However, in recent years, due to the increasing financialization of commodity markets, white precious metals have turned from merely output commodities to actively traded securities. White precious metals could provide an alternate and probably more efficient inflation shield (Batten et al., 2018). Bampinas and Panagiotidis (2015a) suggested a robust time-varying relationship between silver and inflation in the United Kingdom but not in the United States.

McCown and Shaw (2017) investigated the relationship between platinum, palladium and how they evolve in the monetary environments in the U.S. between 1992 and 2015. Correlation findings show that white precious metals outperform gold as an inflation hedge over the time period studied. Furthermore, the authors go one step ahead, claiming that platinum is the superior foreign exchange rate hedge, similar to precious metals' supposed ability to act as international currencies. These findings based on the safe haven approach suggested by Baur and McDermott (2010) also revealed that platinum has a high ability to diversify stock portfolio risks. In a recent investigation, Bilgin et al. (2018) formally examined the inflation hedging effectiveness of white precious metals across various countries. Overall, the conclusion points towards the supremacy of palladium as the most reliable inflation hedge. Furthermore, country-specific graphical evidence uncovers time-variation in the inflation hedging potential of white precious metals.

3.2.2 Interest Rate and Precious Metals

The interest rate is the primary monetary policy tool, which is set by the monetary authorities based on inflation, investment levels, and exchange rate fluctuations that directly influence the price of gold. When the money supply fluctuates, monetary authorities must respond by changing interest rates (Akbar et al., 2019). Inflation expectations have risen in tandem with rising commodity prices, causing the monetary policy to tighten and raise interest rates. A rise in interest rates impacts the price and volatility of commodity markets through several macroeconomic channels. Moreover, interest rate fluctuations can affect construction using copper and silver, among other metals. For instance, industrial metals are critical to manufacturing durables goods (like cars, household appliances, etc.), their demand can influence demand for those types of goods. Profitability also influences investment in plants and equipment that use metals, which affects the cost of financing (Hammoudeh and Yuan, 2008).

Investors are constantly concerned with interest rates, monetary policy direction, and implications for gold and the broader markets (Bernanke et al., 2018). Bernanke (1990) found that the interest rate is the key exogenous variable reflecting monetary policy. Thorbecke and Zhang (2009) examined the effect of unexpected monetary policy changes on commodity prices, specifically silver for the periods of 1974 and 1979 and between 1989 and 2006. Their empirical results for both times are notably different. The federal funding rate increased in response to an expanded demand in response to expected inflation, causing an increase in the price of silver during 1974 and1979. However, a rise in the federal fund rate between 1989 and 2006 led to a decline in the price of money expected to raise the short-term real interest rate. These findings are aligned with Frankel (2006). However, Chan and Mountain (1988) revealed in their research that interest rates were a driver of silver prices but did not impact interest rates.

Following the 2008-2009 financial crisis, central banks used unconventional tools such as Zero Interest Rate Policies (ZIRP) and Quantitative Easing (QE), which Japan pioneered in the early 2000s, to stabilise prices and maximise employment after traditional measures had been exhausted. Negative interest rate policies (NIRPs) were implemented by central banks in several countries between mid-2014 and early2016, including Denmark, the eurozone, Japan, Sweden, and Switzerland, breaking the 'zero lower bound.' This means that commercial banks must pay to keep their deposits with central banks (Tokic, 2017).

However, Palley (2016) argues that the economic establishment's consensus on negative interest rates is dangerously wrong because they contribute to financial fragility create macroeconomics of whiplash. As a result of policy contradictions between today and tomorrow, promote currency wars that undermine the international economy, and foster a political economy that breeds toxic politics. Furthermore, it perpetuates and promotes the flawed model of growth based on debt and asset price inflation, which has already caused so much harm.

The real interest rate is one of the most significant macroeconomic variables influencing investment holdings. Alternative investments become more appealing as the real interest rate tumble and vice versa. Besides, gold can be considered an enticing investment option during low investor confidence (Apergis et al., 2019). Wicksell (1907) first noticed the correlation between gold and the interest rate back in 1907. Gold has been a hedge and stabilising vehicle through emergencies that have led to lower volatility changes in portfolios. Moreover, this is attributable to gold's distinguishing characteristics instead of other assets, namely that it does not perish and is not subject to default threats. Literature suggested that gold has outperformed bonds and equities during periods of recession (Belke, 2013) and (Baur and McDermott, 2010). For instance, as the United Kingdom agreed to exit the European Union in 2016, gold prices soared by $100 in six hours as buyers started to purchase gold in reaction to a declining pound and euro. Similarly, after the financial crisis, gold hit $1000 per ounce in February 2009. The United States' debt ceiling in the wake of the 2008 financial crisis and the Eurozone debt crisis prompted the price of gold to increase from $1000 per ounce in 2009 to $1895 in September 2011 (Amadeo, 2017).

Hence, Investors use gold-prices tend to be inflated in times of crisis or stagnation because they see it as a safe-haven. Furthermore, low gold prices, on the other hand, may indicate a stable economy because investors have a variety of alternative assets to choose from, such as stocks and bonds (Apergis et al., 2019). Gold prices may also provide valuable information on economic activity trajectory and monetary policy's corresponding implementation (Benati and Goodhart, 2010). Given the peculiar properties of gold that encourage buyers to raise their reserves during crisis times, it is critical to comprehend the relationship between the real interest rate and gold prices.

Literature suggests the interest rate has been a standard variable to use in the gold price models. Moreover, many analysts see interest rates, regardless of currency, as an opportunity cost of owning gold, a profit that might have been gained if investors had bought a bond instead. Some ideas then concluded that there may be a negative interaction between the two, but this is a matter of contention (O'Connor et al., 2015). Wang and Chueh (2013) reported that the nominal interest rates have a negative impact on gold prices but a positive impact on oil 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 et al. (2001) and demonstrated that these surprises affect gold prices.

Diba and Grossman (1984) and Fortune (1987) conducted theoretical studies on gold prices and interest rates. Diba and Grossman (1984) suggested a theoretical model to explore the probability of a rational bubble in gold prices. They argued that if a rational bubble exists, the time series of its price, as well as the differenced series, should be non-stationary. According, to the findings, the differenced sequence of gold prices is stationary. Besides, the empirical findings also demonstrated a strong correlation between the time series properties of the relative price of gold and the time series properties of the real interest rate, suggesting that the price of gold reacts to market fundamentals rather than a logical bubble.

Fortune (1987) proposed an asset replacement channel in which gold and nominal interest rates are linked for a specified level of predicted future prices. Furthermore, he contends that rises in anticipated interest rates could enable gold owners to sell gold, as it does not have a cash flow, to invest in interest-bearing assets, thus discouraging new acquisitions of gold by investors. However, Abken et al. (1980) contradicts with the Fortune's assessment and considers the gold and inflation connection as the real driving force behind the gold interest rate link. Furthermore, they claimed that an increase in anticipated inflation would now lead to a similar increase in nominal interest rate. This higher return by means of bonds would lead to similar growth in the rate of gold price appreciation and to a positive relationship.

However, a correlation does not exist in all studies. 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. Furthermore, Lawrence (2003) empirically investigated the linkage between gold and 3 months US Certificate of Deposit rates and found no statistically significant correlation between gold and 3-month US Certificate of Deposit rates, as well as many other macroeconomic variables such as inflation, using quarterly data from 1979 to 2001. Tully and Lucey (2007) also found that interest rates had no significant impact on gold prices by using an asymmetric power GARCH model with inflation and the trade weighted dollar. The only element with explanatory power was the US dollar.

Short Versus Long Interest Rates According to Baur (2011), the relationship between gold and long-term interest rates differs from that of short-term interest rates. 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 (Levin et al., 2006). 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 emphasise the dangers of "correlation as causation" but they believe the association is convincing.

Akram (2009) suggested that the short-term real interest rate decline led to an increase in commodity prices. Moreover, this study also finds that metal prices fluctuated more as expected in response to interest rate changes. 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.

Hammoudeh and Yuan (2008) employed GARCH-based models to examine the conditional volatility and instability of interest rates in the economy and its effect on the prices of three important metals - silver, gold, and copper. Their results indicate that commodity portfolio managers have more opportunities to invest in precious metals like gold and silver than copper (also known as semi-precious or industrial metal) to mitigate the risk in bad times. Moreover, gold and silver are less sensitive commodities to bad and good news, especially in the short run. Hammoudeh and Yuan also revealed an increase in the interest rate slows down the metal market's price volatility, whereas oil shocks have encouraged the investor to invest in precious metals like gold and silver for portfolio diversification.

In emerging economies, Sari et al. (2010) investigated both short and long-run information between uncertainty in Brent oil prices, Turkish interest rate, Turkish Lira/US dollar exchange rate, and spot prices of gold and silver. They have gathered the daily data between March 2003 and March 2007. The evidence of this study shows that oil price shocks have a negative impact on the price of silver as it has a vital role in the industrial sector of Turkey. Whereas, in the short run, the Silver spot price has a strong positive impact on the Brent oil prices as quoted by Istanbul Gold Exchange IGE.

4.1.1 Industrial Production and Precious Metals

We consider industrial production to be an independent variable due to the fact that precious metals are utilised during the manufacturing process. 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 et al., 2010b). Moreover, the authors argued that gold and silver are used in the jewelry industry and traded as investment assets, but silver is more commodity-driven than gold due to its monetary element's gradual replacement. However, the price of platinum is frequently affected by changes in the prices of other precious metals, such as gold. Gold and platinum appear to be moving in lockstep recently, while silver and palladium have moved closer together. Palladium is platinum's poor cousin, but it is catching up because both are used in the automobile industry.

Originally, gold, silver, platinum, and palladium were classified as industrial metals (Vigne et al., 2017). 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. This study reported that white precious metals (silver, platinum, and palladium) sometimes act as safe havens, whereas gold does not work in the USA. Klein (2017) looked at links between developed markets and precious metals based on improvement in the Mensi et al. (2017). Moreover, due to the industrial demand for platinum in the developed markets, it acts as a safe haven during extreme market conditions. In contrast, gold and silver for safe haven appear weakened after 2013, which has been concluded by Sakemoto (2018).

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 et al. (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. Vigne et al. (2017) suggested that the use of white precious metals in the investment can be further enhanced due to the introduction of ETFs, which improved the attractiveness of white precious metals as investment assets and substantially reduces the investment costs in particular for small investors.

The economic factors and interrelationships of gold, silver, platinum, and palladium are distinct (Batten et al., 2010). The market for gold prevails in terms of monetary assets (36% investment holdings and 12% official holdings in 2012) and commodities (43% jewellery 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 and Li, 2015). Moreover, Lucey and Li (2015) reported that the majority of gold products come mainly from gold mines, while only 30% are from silver mines. About 12% of silver pro- duction is actually as a by-production from gold mines confirmed by the World Gold Council. Therefore, the supplies are also not entirely silver-price elastic.

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. The advancement of technology in the automotive industry development and sales changes will significantly impact platinum demand (Alonso et al., 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).

4.1.2 Share Price and Precious Metals

Many researchers (Aktürk (2016); Bampinas and Panagiotidis (2016); Brown et al. (2016); Raza et al. (2016); Alagidede and Panagiotaki's (2010)) reported in their research that stocks movement depends on inflation. As a result, investors prefer to hedge against inflation by investing in precious metals such as gold, silver, and platinum (Ranson and Wainwright, 2005) In the commodity market, only gold can per- form against inflation, except when there are large inflation shocks exist (Iqbal, 2017).

Portfolio diversification plays a significant role in mitigating the investor's risk in the highly volatile financial markets. In general, investors pursue assets with acceptable average returns and a negative relationship with stock and bond portfolios (Froot, 1995). Jaffe (1989) and Chua et al. (1990) have investigated the investment advantages of adding precious metals to U.S. portfolios and revealed that positive allocations improve overall performance. Hillier et al. (2006) also examined the relative benefits of investing in gold, silver, or platinum in addition to the S&P 500 from 1976 to 2004. The authors found that regardless of which precious metal is added, portfolio performance generally improves. Furthermore, they suggested that gold provides the most incremental benefit, while silver offers the least.

Sensoy (2013) reported 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 and Ghosh, 2013).

Most of the literature studies investigated whether gold is a secure port or whether a local or national stock exchange ETF portfolio is a hedge (Coudert and Raymond, 2011; AlKulaib and Almudhaf, 2012; Ghazali et al., 2013). Gold is a powerful tool for protecting risk and diversifying financially. Conover et al. (2009) extended the literature along several significant dimensions and evidenced the benefits of adding precious metals to U.S. equity portfolios. By and large, their findings indicate that in-vectors could significantly improve portfolio performance by increasing their exposure to precious metals firms' equities.

Baur and McDermott (2010) highlighted the significance of yellow metal (gold) and suggested that it is an essential instrument for financial crisis hedging or diversification. Furthermore, they reported that gold 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. Similarly, Ghazali et al. (2013)) used data from July 2001 to February 2013 in Malaysia to determine whether gold is a hedging tool or a safe haven, especially during financial crises. The findings suggest that gold plays a significant hedging role, but that role remains for a limited period. Ziaei (2012) examined the relationship between the stock markets in Indonesia, Malaysia, the Philippines, Singapore, Thailand, China, Japan, and South Korea and the gold prices. The study's findings indicate a negative and statistically relevant association between these stock exchange markets and gold prices.

To determine whether the relationship between gold and equity returns shifts when markets go into decline, Ibrahim (2011) studied equity returns in Malaysia. A statistical analysis using 2,261 observations from August 1, 2001, to March 31, 2010, found a positive and meaningful relationship between the change in gold and equity returns. However, the results concluded that this relationship has a low correlation and that consecutive negative market returns did not improve the relationship during times of financial uncertainty. Besides, the study results indicate gold investments have the potential to provide benefits during stock market downturns and gold could be used as a safe haven for local investors.

Arouri et al. (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. However, Hoang (2011) examined the shifts in returns for gold trading on the Paris stock market from 1950 to 2003 and reported that gold offers lower returns than financial assets such as stocks and bonds. This study opens up a new debate that gold is an effective hedging tool in various financial markets, but this statement is not valid for some markets.

Baur and McDermott (2010) investigated gold's position in the global financial system and to test whether gold is a safe haven against the stocks of significant emerging and developed countries. Moreover, this study revealed that gold provides both a hedge and safe haven properties for major European stock markets and the US, but not for Australia, Canada, Japan, or significant emerging markets such as the BRIC countries. Chen and Lin (2014) studied the relationship between gold and stocks in four severe bear markets (S&P500 index (broad large-cap market), Dow Jones index (30 industry leaders of the economy), NASDAQ Index (technology sectors), Russell 2000 index (small-cap market) and Russell 3000 index (US equity universe)) where prices rose dramatically since the 1960s. The findings suggest that gold is a vital hedging option in stock markets during times of rapid price declines.

However, when the economy was growing, gold was not treated as a hedging weapon except for small company stocks. Wai et al. (2014) analysed the impact of gold prices on stock market performance. According, to the study's findings, gold prices interacted with Malaysian, Thai, and Indonesian stock markets. Choudhry et al. (2015) examined the non-linear dynamic movements of gold returns, equity returns, and stock volatility in the stock markets of England (FTSE100), the United States (S&P500), and Japan (Nikkei225) during the global economic crisis. In static market conditions, the findings show that gold was not used as a hedging weapon in seven stock markets. Given the above findings of studies on gold suggest that gold can be used as an essential portfolio diversification method in financial markets.

The relationship between financial markets and gold has been extensively examined in the literature. However, few studies exist on white precious metals such as silver, platinum, and palladium (Tuna, 2019). Hillier et al. (2006) investigated the significance of three precious metals (gold, silver, and platinum) in the USA stock market. This study's findings suggested that these three precious metals have low correlations with US equity markets and can be used for portfolio diversification and hedging. Similarly, Conover et al. (2009) studied the effect of gold, silver, and platinum in the USA stock market. However, their study results suggested that gold provides better protection against inflation compared to silver and platinum. Furthermore, Conover et al. (2009) and Jain and Ghosh (2013) reported that platinum is a good hedging and portfolio performance-enhancing tool.

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. On the other hand, Low et al. (2016) analysed whether investors preferred to include precious metals such as gold, silver, platinum, and palladium in their portfolios as jewellery or index investments for Australia, Germany, China, the United States, England, Brazil, and France from 2003 to 2013. The results indicate that these precious metals' investments were preferred more than the indices for which these precious metals were the underlying assets.

Lucey and Li (2015) examined when gold, silver, platinum, and palladium were considered secure investment instruments for local US investors between 1983 and 2013. Lucey and Li's results demonstrate that silver, platinum, and palladium are viable investment alternatives when gold is not viable. On the other hand, if we see the south most African continent region, where the South Africa export is highly dependent on the two precious metals, i.e., Gold and platinum. This research provides a more detailed comparison of views on whether these two precious metals (Gold & Platinum) can help the stakeholders forecast inflation for South Africa domestically or not. Furthermore, the study finds that forecaster must consider these precious metals (Gold & platinum) in the process of forecasting domestic inflation (Balcilar et al., 2017). Bailey and Bhaopichitr (2004) also examined the significance of silver in uncertain stock market environments, determining whether or not this precious metal has the ability to 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.

3.2.3 Unemployment Rate and Precious Metals

Unemployment is another macroeconomic factor that can have a positive or negative effect on precious metals. The majority of studies published in the literature examined the relationship between the unemployment rate in the United States and the price of precious metals. For instance, Thaver and Lopez (2016) analysed the relationship between gold prices and the US unemployment rate over three different time periods: 1978-2016, 1990-2016, and 2008-2016. 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 un- employment 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.

Yin and Han (2016) also proved a significant impact of macroeconomic factors on commodity markets in China, whereas US macroeconomic factors have more impact on the commodity market than China in terms of the size of coefficients their level of significance. Delatte and Lopez (2013) found that inflation is directly related to buyers' buying power and has a considerable impact on investors' behavior, who wants to invest in the commodities. Furthermore, they reported that a prudent investor could not ignore the element of inflation in the process of portfolio making.

Literature suggests that the impact of the unemployment rate on metal markets has primarily been examined in the developed economy, particularly in the U.S. metal market. Therefore, there is a substantial impact of U.S. macroeconomic news announcements on the return, unemployment rate containing enough information to cause the metal market (Elder et al., 2012). Cai et al. (2001) analysed 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 et al. (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. Hence, fund managers should include unemployment reports when making the construction portfolio.

However, Smales and Yang (2015) examined the prices of gold that respond briskly due to the commodity market's macroeconomic announcements. Furthermore, the study found that the unemployment rate and GDP's macroeconomic announcements significantly impact precious metals prices. Becker et al. (1996) reported 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. Similarly, Balduzzi et al. (2001) examined in the study to see the impact of the macroeconomic announcement on prices and volume of trading of bond prices. Practitioners often study different data sets on precious metals, such as silver and gold to address macroeconomic indicators, such as the CPI, unemployment rate, GDP and many other factors together (Cecchetti et al., 2000). Additionally, Apergis et al. (2014) found that a higher unemployment rate has a negative effect on the price of silver. Recently, Caggiano et al. (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.

3.3 Methodology and Data

The most important aspect of the time series analysis is to apply the appropriate methodology for time series data as the wrong model specification or the wrong procedure offers partial and inaccurate estimates. The time series analysis method is primarily determined by the unit root test results, which establish the variable's stationarity. Furthermore, the techniques used to evaluate stationary time series cannot be used to analyse non-stationary time series. Supposedly, if all relevant variables are stationary, the approach becomes straightforward and unbiased estimates can be obtained using ordinary least squares (OLS) or vector autoregressive (VAR) models. However, if all the variables are non-stationary, ordinary least square (OLS) or vector autoregressive (VAR) models can be ineffective for analysing the relationship (Shrestha and Bhatta, 2018a). Similarly, when the study variables are of the mixed form, i.e., some are stationary, and others are non-stationary, an additional issue occurs (Nkoro et al., 2016). In this study, we adopt improved cointegration test models (Johanson cointegration test or An autoregressive distributed lag (ARDL) bound testing approach) suggested by Johansen and Juselius (1990) and Pesaran et al. (2001). This study examines the relationship between macroeconomic factors and precious metals prices across developed and emerging markets. Our null hypo- thesis is that there is no significant relationship between precious metals prices and macroeconomic variables across developed and emerging markets.

3.3.1 Data Description

The purpose of this research is to determine the effect of six major macroeconomic variables (inflation, industrial development, short-term and long-term interest rates, share prices, and unemployment rate) on precious metals prices. The log prices of gold, silver, platinum, and palladium have been used to stabilize the variance of a series. The data of precious metals prices derived by taking logarithmic differences of the monthly closing prices of Gold, Silver, Platinum, and Palladium as published by Thomson Reuters in domestic currency in terms. We also used the monthly closing prices of the dependent and independent variables. This is because the daily data for the independent variables were not readily available in the various economies that are being investigated. In addition, the monthly number of observations were sufficient for conducting the purpose of economic analysis. Also, the time frame beyond 2020 was not considered because the data at the time was not accessible at the time of the collection of data. Therefore, we have taken this study period from January 1979 to September 2020, including 501 maximum and 85 minimum monthly time series observations due to the absence of data for different countries before and after the sample period.

Macroeconomic and financial factors cause dynamic precious metal market fluctuations (Tully and Lucey, 2007, Batten et al., 2015, Mo et al., 2018). Strongin and Petsch (1995) and Gorton and Rouwenhorst (2006) provided evidence that there is a correlation between shifts in the overall economy and the prices of commodities. Trading methods for financial markets and precious metals markets also suggest that there is a relationship between trading outcomes and price volatility. Pesaran and Timmermann (1995) suggest that macroeconomic factors might assist in increasing trading outcomes in equities markets using timing-based trading methods. Also, Vrugtet al. (2004), Chan and Young (2006), and (Batten et al.,2010) analysed several trading methods in commodities markets, including ones that are tied to the business cycle which supports the relationship between macroeconomic variables and precious metals volatility. Furthermore, Li and Lucey (2017) and Huynh (2020) have extended the analysis using Economic Policy Uncertainty (EPU), a key economic component associated to high-volatility markets like precious metals.

The primary goal of this study is to investigate the effect of macroeconomic factors on the pricing of precious metals across both developed and emerging economies. To achieve this objective, we study the six major macroeconomic factors of volatility in the markets for gold, silver, platinum, and palladium. The findings of this study contribute to what is already known about the effects of macroeconomic factors on the dynamics of commodity prices, including examinations of the gold market (Koutsoyiannis, 1990; Cai et al., 2001; Levin and Wright, 2006), silver market (Christian, 2008), gold, silver, platinum and palladium market (Batten et al.,2010) and the joint impact of oil and interest rate shocks on gold, silver and copper prices (Hammoudeh and Yuan, 2008).

We use six predictors in our empirical research that are known to be essential for precious metals in terms of the economic and industrial applications of these metals (see the description of the study variables and source are summarized in Table 3.1).

Table 3.1: Variable Description

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

The rational in choosing the explanatory variables for the present study are largely follows studies. Batten et al. (2010) investigated the long-term dynamic relationship between inflation and the price of gold and determined that the gold–inflation relationship is significantly time-dependent. In addition, changes in interest rates have a substantial impact on the relation between gold and inflation, indicating gold's monetary role as a commodity. The findings of Hoang et al. (2016) suggested that gold is never a hedge in the long term, but in the short run for the United Kingdom, the United States, and India. In addition, results published by Beckmann and Czudaj (2013) revealed that gold is a moderately effective hedge against inflation. As a result, the idea that gold may serve as a hedge against economic instability is still up for debate (Lucey et al., 2017).

The interest rate is the key monetary policy instrument established by the monetary authorities based on inflation, investment levels, and exchange rate variations, which directly affect precious metal prices (Akbar et al., 2019). The literature suggests varying level of findings for short-term and long-term interest, and there are number of outcomes, that warrants evaluating long-term and short-term interest rates as an explanatory variable. For instance, the findings of Baur (2011) demonstrated that the correlation between gold and long-term interest rates is distinct from the correlation between gold and short-term interest rates. The results of Baur (2010) 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. Both studies found that a negative relationship existed between gold and interest rates. This apparent paradox seems to imply that short-term interest rates present an opportunity cost to an investor, while long-term interest rates represent inflation expectations.

Industrial production is another predictor for this research since extensive industrial usage of precious metals caused substitution among close metal relatives like platinum and palladium (Sari et al., 2010). Jain and Ghosh (2013) observed that investors typically acquire precious metals as a hedge against the risk of price co-movement induced by the prevalent industrial usage of precious metals.

In the context of the global economy, the tension between the United States and China, the two largest economies in the world, has been getting more difficult, which has sparked concerns about a downturn in the global economy (Bernanke et al., 1994). Many industry professionals have issued dire warnings that a protracted trade war between the United States and China might result in yet another worldwide economic meltdown. At times of extreme uncertainty, precious metals, which are believed to be secure investment assets, outperform standard assets, such as stocks or bonds (Hillier et al., 2006, Baur and McDermott, 2010, Lucey and Li, 2015).

The rationale for selecting an unemployment rate is another example of a macroeconomic factor that has the potential to either positively or negatively affect precious metals. The extensive research that was published in the literature investigated at the association between the rate of unemployment in the United States and the price of precious metals. However, the innovative nature of this research is that for the first time the impact of macroeconomic factors, identified above, are investigated for precious metals across developed and emerging markets for each of the selected economies. The unit root test statistics of the conventional Augmented Dickey Fuller Test (ADF) and Phillips and Perron (PP) test are first considered to assess the degree of cointegration. Then we applied the Johansen and other multivariate cointegration analyses, but the data must be non-stationary at the level. Furthermore, we used the ARDL cointegration technique to ascertain the long-run relationship between series
with varying integration orders (Pesaran et al., 1995, 2001). Although the ARDL cointegration technique does not require pre-testing for unit roots, we believe that the unit root test should be performed to determine the number of unit roots in the sequence under consideration in order to prevent the ARDL model from collapsing in the presence of an integrated stochastic pattern of I(2) (Nkoro et al., 2016). This is discussed in greater detail in the following section.

3.3.2 Descriptive Statistics

The descriptive statistics of the data are summarized in Tables 3.2, 3.3, 3.4 and 3.5. These tables contain information on each market (country), including the mean, standard deviation, minimum and maximum prices, skewness, kurtosis of four precious metals prices, and information about major economic factors for each market. Tables 3.2, 3.3, 3.4 and 3.5 demonstrate that the mean values of four precious metal prices and the major macroeconomic variables substantially vary across developed and emerging economies. Moreover, it can be seen from the mean value that gold in Japan, India, China, and Mexico, silver in China, and Mexico are the most expensive. In all four precious metals and major economic indicators, we found a low standard deviation across developed and emerging economies, indicating that the data is clustered closely around the mean. This shows that the price volatility of four precious metals and macroeconomic indicators are less volatile and consistent across developed and emerging economies. However, the short-term interest rates in the Gold UK, Silver UK, Silver USA, Platinum UK, Platinum USA, Palladium USA, and Platinum long-term interest rates are highly volatile.

From the perspective of skewness, all precious metals prices are skew to the right, with the exception of gold prices in Japan, India, Mexico, platinum prices in Australia, the United States, and China, which are skew to the left. However, the skewness results for macroeconomic variables are mixed, with the bulk of major macroeconomic indicators skewing to the left across developed and emerging countries with only a few outliers. Finally, as can be observed from the kurtosis, the dataset depicts in Tables 3.2, 3.3, 3.4 and 3.5 has lighter tails than a normal distribution. However, few variables, such as gold, silver, and platinum IP in the United Kingdom, gold IP and SIR in Japan, and gold and silver UR in China, exhibit leptokurtic distribution, which has the features of a peak and a fat tail. In addition, there are no outliers to be seen in the findings of Gold Mexico in Table 3.2. This is because the monthly prices have a lower degree of volatility as compared to daily returns volatility.

Table 3.2: Descriptive Statistics – Gold

Country	Variable	Mean	Median	SD	Max	Min	Skewness	Kurtosis
UK	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
	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	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	-	-	-	-	-	-	-
	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
Switzerland	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	-	-	-	-	-	-	-
	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
Japan	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
	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

Country	Variable	Mean	Median	SD	Min	Max	Skewness	Kurtosis
USA	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
	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
China	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	-	-	-	-	-	-	-
	SP	4.30	4.33	0.19	4.86	4.00	0.21	2.58
	IR	1.12	1.18	0.06	1.18	1.03	-0.29	1.24
	UR	1.21	1.19	0.12	1.57	0.99	1.00	4.40
India	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
	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	-	-	-	-	-	-	-
Mexico	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
	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		0.23	1.79	0.74	-0.08	2.39

Notes: The mean values are based on the monthly closing prices of the dependent and independent variables for the countries under investigation.

Table 3.3: Descriptive Statistics – Silver

Country	Variable	Mean	Median	SD	Max	Min	Skewness	Kurtosis
UK	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
	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
Switzerland	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	-	-	-	-	-	-	-
	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
USA	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
	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
China	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
	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
	IR	1.12	1.18	0.06	1.18	1.03	-0.29	1.24
	UR	1.21	1.19	0.12	1.57	0.99	1.00	4.40
India	Silver	10.61	10.58	0.13	11.03	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
	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	-	-	-	-	-	-	-
Mexico	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
	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

Notes: The mean values are based on the monthly closing prices of the dependent and independent variables for the countries under investigation.

Table 3.4: 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	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	-	-	-	-	-	-	-
	SP	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
China	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
	IP	2.16	2.13	0.37	3.03	1.67	0.68	2.23
	SP	4.30	4.34	0.19	4.86	4.00	0.21	2.56
	IR	1.12	1.18	0.06	1.18	1.03	-0.24	1.14
	UR	1.21	1.19	0.12	1.57	0.99	1.04	4.46

Notes: The mean values are based on the monthly closing prices of the dependent and independent variables for the countries under investigation.

Table 3.5: Descriptive Statistics – Palladium

Country	Variable	Mean	Median	SD	Max	Min	Skewness	Kurtosis
USA	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
	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
Australia	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	-	-	-	-	-	-	-
	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

Notes: The mean values are based on the monthly closing prices of the dependent and independent variables for the countries under investigation.

3.3.3 Unit Root Test and Stationarity Tests

The primary purpose of a stationary test is to determine whether the data has a unit root. While modelling time-series data, the most critical issue to address is testing stationarity or unit root properties. If the mean, variance, and auto-covariances of a series are constant for each lag, the series is stationary. On the other hand, If the series is not stationary, it must possess unit root properties. This indicates that the data series' mean, variance, and autocovariance are not constant. If the non-stationarity series use to estimate any regression model, the resulting estimators would be biased. Although the findings appear to be outstanding and spectacular, the regression results are spurious or nonsense (Islam and Habib, 2016). Several statistical tests have been developed in order to determine whether or not the series is stationary. The Augmented Dickey-Fuller tests (Dickey and Fuller, 1979, 1981) and (Phillips and Perron, 1988; Perron, 1990) are the most commonly used methods for testing procedures. We employ two-unit root tests, Dickey and Fuller (1979) and Phillips and Perron (1988), as the data must be stationary to perform regression analysis. The following ADF test model allows for comparing the null hypothesis that a series has a unit root ($a = 0$) against an alternative that series is stationary ($a < 0$).

$$\Delta xt = \alpha x_{t-1} + \sum_{i=1}^{k} \beta \, \Delta x_{t-1} + \varepsilon_t \qquad \textit{Equation 12}$$

In equation 12, where Δ denotes the first difference, x_t denotes the series to be tested, t represents the time trend, and k means the number of lags as determined by some model selection criteria. Phillips and Perron (1988) and Perron (1990) developed a non-parametric testing procedure similar to the ADF test but with the ability to correct for auto-correlated residuals.

We use the null hypothesis for unit root that the data do not have a unit root, implying that they are non-stationary. Moreover, the data has tested for stationarity in both tests at both log levels and their first differences. To investigate the relationship of various macroeconomic variables (Inflation, Short-term and Long-term Interest rate, Share Price, Industrial Production, and Share Price) on the prices of precious metal (Gold, Silver, Platinum, and Palladium), we used ordinary least squared (OLS) model as the main regression model. The log prices of precious metals have been taken as the dependent variable, and the various macroeconomic variables have been taken as the independent variable. Furthermore, we have attempted to identify the macroeconomic variables that significantly impact the precious metals prices.

The multivariate linear regression model used in this study is as follows:

$$p_t = \alpha + b_1 CPI + b_2 IP + b_3 SP + b_4 SIR + b_5 LIR + b_6 UR + \varepsilon_t \text{ Equation 13}$$

where p_t is the log prices of precious metal prices at t, where CPI is the log prices of consumer price index, IP is the log prices of industrial production, SIR is the log prices of short-term interest rate, LIR is the log prices of long-term interest rate, UR is the log prices of unemployment rate and ε_t is an error term.

Firstly, we converted the variables to logarithmic form. Then, we investigated whether our variables are stationary or not. If the variables are non-stationary at level, we transformed them into their 1st differences. The differenced series was then examined again for the presence of unit root properties. Once the variables have time-invariant mean, variance, and auto-covariance, it is said to be stationary and can be used to run a linear regression model. We have used the Dickey and Fuller (1979) and Phillips and Perron (1988) test to check for variables' stationarity. The null and alternate hypothesis for both these tests are:

H0: $\rho = 1$ Unit Root [Variable is non − stationary]

H1: $\rho < 1$ No Unit Root [Variable is stationary]

The H_o may be rejected if the ADF statistics exceed the critical value. As a result, the H_1 assumption is made, indicating that the data are stationary.

3.3.4 Time Series Model Selection

The appropriate methodology for time series data is the most critical part of time series analysis. The incorrect specification of the model or application of the results of the faulty methods leads to biased and unreliable estimates. If all variables are stationary, the data is I(0) in levels, then we can directly apply OLS. OLS is a single equation technique, which means that we can only use it for a single equation. Similarly, when we have multiple equations or simultaneous equations, where we have more than one set of endogenous variables and the data been stationary at a level in all variables, we apply the VAR model. (Vector Autoregressive Model). The equation 14 will be like.

$$Y = \alpha + \beta_1 Y + \beta_2 Z + \beta_3 A \qquad \text{Equation 14}$$

If variables are I(1), which means that they are non-stationary in levels but become stationary at the first difference, then we cannot use OLS directly because the regression at this level would be spurious. As a result, we apply test for cointegration using test suggested by Johansen and Juselius (1990). Therefore, we must determine whether these variables exhibit cointegration. Then there are two additional possibilities, cointegration exists or not. Thus, if cointegration exists in a single equation, we can directly apply OLS to level data, whereas we should use the (VECM) Vector Error Correction Model for multiple equations. In contrast, if cointegration does not exist, we cannot use OLS or Vector Error Correction Model on level data; instead, we must use OLS/VAR on the first difference data. Lastly, if variables are of a mixed order if integration, that is some variables are stationary in levels while others are stationary first differences, an Autoregressive Distributed Lag (ARDL) approach should be used as shown in Figure 3.18.

Figure 3.18: Time Series Model election

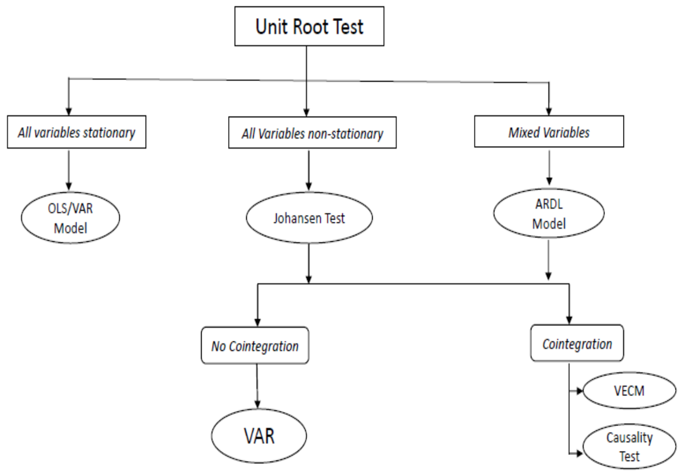


Figure 3.18 Source: Shrestha and Bhatta (2018).

3.3.5 Johansen Cointegration Test

Engle and Granger (1987) made significant contribution to time-series econometrics by proposing a method for testing cointegration relationships between non-stationary variables. They defined cointegration as the condition under which two non-stationary variables at the level produce a variable with a lower order of integration when their linear combination occurs. The Engle-Granger two-step method (Engle and Granger, 1987) and the Johansen procedure (Johansen, 1988; Johansen and Juselius, 1990) are the two most frequently used approaches for testing the cointegrating relation. The effectiveness of these tests may be distorted by the presence of breaks and structural shifts in a large number of economic time series. As a result, numerous cointegration tests for both single equations and systems have been developed.

There are two test statistics in the Johansen system for determining cointegration in bivariate and multivariate frameworks, namely the trace test and the maximum eigenvalue test. The trace test can be used to determine whether the number of cointegrating vectors is less than or equal to k against an alternative that there is a greater than k cointegration relationship. The maximum eigenvalue test determines whether the number of cointegrating vectors is k or an alternative k + 1 cointegration relationship (Johansen and Juselius, 1990).

Johansen et al. (2000) extended the cointegration test developed by Johansen et al. (1995). They suggested an analysis of cointegration in the presence of structural disruptions in the deterministic trend. They have developed a model for cointegration with well-defined breakpoints by handling distinct types of shifts in the series considered by Perron (1988; 1990). The first shift occurs at the level of the process, the second shift occurs at the change in the slope of the trend, and the third shift occurs at the point where both shifts take place.

Johansen's cointegration method implicitly assumes that variables are non-stationary at the level. However, it becomes stationary after first differencing. Moreover, this method investigates a Vector Autoregressive (VAR) model of Y_t, an (n x 1) vector of variables that are integrated of the order one—I(1) time series (Beag and Singla, 2014). This VAR can be expressed as equation 15:

$$\Delta Y_t = \mu + \sum_{i=1}^{\rho-1} \Gamma Y_{t-1} + \Pi Y_{t-1} + \varepsilon_t \qquad \text{Equation 15}$$

In equation 15, where Γ and Π are matrices of parameters, ρ is the number of lags (selected on the basis of Schwarz information criterion), ε_t is an (n × 1) vector of innovations. The existence of at least one cointegrating relationship is needed for the study of the long-run relationship of the prices to be plausible. Johansen suggested two probability ratio tests to detect the number of co-integrating vectors: the trace test and the maximum eigen value test, which are shown in equations 16 and 17, respectively.

$$J_{Trace} = -T \sum_{i=r+1}^{n} ln(1 - \hat{\lambda}_i) \qquad \text{Equation 16}$$

$$J_{Trace} = -T ln(1 - \hat{\lambda}_r) + 1 \qquad \text{Equation 17}$$

where, T is the sample size and $\hat{\Lambda}_i$ i is the i^{th} largest canonical correlation. The trace test compares the null hypothesis with r cointegrating vectors to the alternative hypothesis with n cointegrating vectors. In contrast, the maximum eigen value test compares the null hypothesis of r cointegrating vectors to the alternative hypothesis of $r + 1$ cointegrating vectors (Hjalmarsson and Österholm, 2010).

3.3.6 Vector Error Correction Model (VECM)

Cointegration is possible only between variables integrated in the same order, and the unit root tests will assist us in determining whether variables are integrated with the same order or I (1) (Maysami and Koh, 2000). Prior to estimating the Vector Error Correction Model (VECM), we perform augmented Dickey-Fuller (ADF) and Phillips-Peron (PP) tests on the variables in levels and first differences to ensure stationarity and unit-roots. The two-step error-correction model developed by Engle and Granger (1987) can also be applied in a multivariate context, but the VECM produces more efficient estimators of cointegrating vectors.

As a full information maximum likelihood estimation model, the VECM allows for testing for cointegration in a system of equations in a single step and without the need to normalise any specific variables. This avoids the errors from the first step from being carried over into the second step, which would be the case if Engle-methodology Granger's were used instead. As an added benefit, no a priori assumptions about the endogeneity or exogeneity of the variables must be made when using this method. In this case, the VECM has the following form:

$$\Delta Y = \sum j = 1k - 1\Gamma_j \, \Delta Y_{t-j} + \alpha\beta \, Y_{t-k} + \mu + \varepsilon_t \qquad \text{Equation 18}$$

In equation 18, where $\sum^{k-1} j = 1\Gamma\Delta Y_{t-j}$ and αβ´ Yt−k are the vector autoregressive (VAR) component in first differences and error-correction components, respectively, in levels of Eq. (18). Yt is a p × 1 vector of variables and is integrated of order one. μ is a p × 1 vector of constants. k is a lag structure, while t is a p × 1 vector of white noise error terms. Γj is a p × p matrix that represents short-term adjustments among variables across p equations at the jth lag. β0 is a p × r matrix of cointegrating vectors, and Δ denotes first differences. α is ap × r matrix of speed of adjustment parameters representing the speed of error correction mechanism. A larger α indicates a more rapid convergence to long-run equilibrium in the presence of short-run deviations from it.

3.3.7 Vector Autoregression Model (VAR)

Vector Autoregression Model (VAR) is one of the most widely used and most successful models for the analysis of multivariate time series because it is versatile and easy to apply, as well as being very successful. Moreover, it has proven to be particularly useful for understanding the dynamic behaviour of economic and financial time series, as well as for forecasting (Zivot and Wang, 2006). Exogenous variables are not required in the basic VAR model because it assumes that all regressors are endogenous. Below is the simplified VAR dimension I for two variables X and Y with a single lag.

$$Y_t = \delta_1 + \theta_{11} Y_{t-1} + \theta_{12} X_{t-1} + \epsilon_{1t} \qquad \textit{Equation 19}$$

$$X_t = \delta_2 + \theta_{21} Y_{t-1} + \theta_{22} X_{t-1} + \epsilon_{2t} \qquad \textit{Equation 20}$$

In equation 19 and 20 where ε_{1t} and εε_{2t} are uncorrelated white noise disturbances or stochastic error terms. We choose Akaike Information Criterion (AIC) to get the appropriate lag length is important in VAR modeling. Autoregressive Distributed Lag Approach (ARDL)

When there is only one cointegrating vector, the cointegration method proposed by Johansen and Juselius (1990) cannot be used. As a result, it is critical to investigate the Autoregressive Distributed Lag (ARDL) approach to cointegration or bound procedure proposed by Pesaran et al. (1995) and Pesaran et al. (2001), regardless of whether the underlying variables are I(0), I(1), or a combination of both. In such cases, the ARDL approach to cointegration can provide accurate and efficient estimates. In contrast to the Johansen and Juselius (1990) cointegration method, the Autoregressive Distributed Lag (ARDL) approach to cointegration aids in the identification of the cointegrating vector(s). To examine the relationships between selected study variables, we employ the ARDL bounds testing approach suggested by Pesaran et al. (2001). This method has a range of advantages compared to the Johansen cointegration approach (Johansen and Juselius, 1990). The first advantage is that it necessitates a smaller sample size than the Johansen cointegration method (Ghatak and Siddiki, 2001). Second, Johansen's method necessitates that the variables be integrated in the same order. The ARDL method does not require that variables be integrated in the same order. It can be used if the variables are purely I(0) or I(1) or mutually cointegrated. Thirdly, the ARDL method yields unbiased long-run estimates with valid t statistics if any model regressors are endogenous (Narayan, 2005; Odhiambo, 2009). Fourthly, this approach enables simultaneous evaluation of one variable's short and long-run effects on another and the separation of short and long-run effects (Bentzen and Engsted, 2001).

Moreover, the model of ADRL approach has enough lags to capture the data generation process in a general-to-specific modelling framework (Laurenceson and Chai, 2003). The ARDL method estimates $(p + 1)^k$ regressions to obtain the optimal lag-length for each variable, where p is the maximum lag to be used and k is the number of variables in the equation. Furthermore, model selection criteria such as adjusted R^2, Akaike Information Criteria (AIC), and Schwartz-Bayesian (SBC) criteria can be used to pick the model. SBC is known as the parsimonious model (it selects the shortest relevant lag-length), while AIC and modified R^2 are known for selecting the longest relevant lag-length. This study reports on the models based on these three parameters. Finally, the ARDL method yields robust results for cointegration analysis with a smaller sample size. As in few countries the sample size is limited, this provides additional impetus for the study to take this approach (Yusof and Majid, 2007). We use natural logarithm variables to determine the significance of the relationship between macroeconomic variables and precious metals prices. The following ARDL model is used to analyse the relationship between these variables.

3.4 Empirical Results and Discussion.

3.4.1 Unit Root Test and Stationarity Tests Results

To test unit root properties of variables, unit root tests are employed to test the stationarity and non- stationarity. The calculated value of test statistics and the tabulated value (tau1, tau2 and tau3 for ADF and Ztau for PP) are used as a 'rule thumb' to determine if the calculated value of test statistics is greater than a tabulated value at 5% confidence level for this study. We can reject the Null Hypothesis, i.e., Ho: Unit Root exists in the Data Series. Hence, in this case, we accept the null hypothesis, and the data is non-stationarity, and we have to take the first difference. The results of both the unit root tests are presented as follows.

The results of the ADF and PP tests are displayed in Tables 3.6 up to and including 3.25 for Gold Australia, Gold USA, Gold UK, Gold Switzerland, Gold Mexico, Gold Japan, Gold China, Gold India, Silver India, Silver Switzerland, Silver Mexico, Silver China, Platinum Australia, Platinum USA, Platinum UK, Platinum China, Platinum Australia, Platinum USA, Platinum UK, Platinum China, Palladium USA, and Palladium Australia, respectively.

The unit root exists in all variables, as shown in Tables – 3.6, 3.8, 3.12, 3.13, 3.19, 3.20, 3.21, 3.23, 3.24 and 3.25. As a result, we are unable to reject the null hypothesis and conclude that all macroeconomic variables in Gold Australia, Gold Japan, Gold China, Gold India, Silver India, Platinum USA, Platinum UK, Platinum China, Palladium USA, and Palladium Australia are non-stationary at the level. Thus, we converted non- stationary variables to their first differences before running the regression model, and all macroeconomic variables became stationary at the first difference. On the other hand, the results of Tables 3.7, 3.9, 3.10, 3.11, 3.14, 3.16, 3.17, 3.18, 3.19 and 3.23 indicate that all variables except CPI have a unit root. The results suggest that we cannot reject the null hypothesis and conclude that all macroeconomic variables in Gold Switzerland, Gold United Kingdom, Gold United States of America, Gold Mexico, Silver United States of America, Silver United Kingdom, Silver Switzerland, Silver Mexico, Silver China, and Platinum Australia are non-stationary at the level. However, the CPI time series data illustrate the stationarity of the data at the level. To address that difference, we converted non-stationary variables to their first differences, and all macroeconomic variables became stationary at the first difference, except for the CPI, which is already stationary at level.

3.4.2 Johansen Cointegration Test Results

The Johansen trace test is employed to determine whether the variables are cointegrated. Furthermore, the Trace and Max Eigenvalue (TME) statistics are used to analyse the results of Johansen Cointegration. The hypothesis of the Johansen test suggests if the H_o holds, there is no cointegration. Therefore, if the TME values exceed than its critical value, which is 5% in this case, we reject H_o, indicating cointegration. However, if the trace and Eigenvalues yield different results, the trace statistic value is preferable, as suggested by Lüutkepohl et al. 2001. The model lag length selection was determined by Akaike (AIC) Information Criterion, and the lag length varies across metals and countries. The unit root results reported in Table 3.6 suggests that the variables such as Gold (Australia, Japan, China, India), Silver (China, India) Platinum (USA, UK, China), Palladium (USA, Australia) satisfy the pre-requisite condition for the application of the Johansen cointegration test, that is the series considered are integrated of order 1. The results of Johansen's maximum likelihood tests (maximum eigenvalue and trace test) are given in Tables 3.26, 3.27, 3.28 and 3.29.

Table 3.26: 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	35.25	38.33	0.10
	At most 3	48.74	63.88	0.47	19.32	32.12	0.70
	At most 4	29.43	42.91	0.53	15.87	25.82	0.55
	At most 5	13.56	25.87	0.69	8.09	19.38	0.81
	At most 6	5.46	12.52	0.53	5.464	12.51	0.53
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 the aforementioned measures were calculated using monthly time series data obtained from the sources listed in Table 3.1.

Table 3.27: 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	24.53	38.33	0.70
	At most 2	55.84	63.87	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	18.91	25.87	0.28	10.89	19.38	0.52
	At most 5	8.026	12.51	0.24	8.026	12.51	0.24
India	None*	120.23	117.7	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	63.87	0.56	19.82	32.11	0.66
	At most 3	27.01	42.91	0.68	15.48	25.82	0.59
	At most 4	11.53	25.87	0.84	7.84	19.38	0.83
	At most 5	3.69	12.51	0.78	3.69	12.51	0.79

Source: All the aforementioned measures were calculated using monthly time series data obtained from the sources listed in Table 3.1.

Table 3.28: 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	150.56	0.00	70.86	50.59	0.00
	At most 1*	128.43	117.70	0.00	50.69	44.49	0.00
	At most 2	77.74	88.80	0.24	30.27	38.33	0.31
	At most 3	47.46	63.88	0.53	21.27	32.11	0.55
	At most 4	26.19	42.91	0.73	13.44	25.82	0.76
	At most 5	12.75	25.87	0.76	7.64	19.38	0.85
	At most 6	5.11	12.51	0.58	5.11	12.51	0.58
UK	None*	163.78	125.61	0.00	58.88	46.23	0.00
	At most 1*	104.90	95.75	0.01	37.59	40.07	0.09
	At most 2	67.31	69.81	0.08	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	32.1	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	4.64	12.51	0.65	4.63	12.51	0.64

Source: All the aforementioned measures were calculated using monthly time series data obtained from the sources listed in Table 3.1.

Table 3.29: 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	47.81	44.49	0.02
	At most 1	67.48	88.80	0.60	29.99	38.33	0.32
	At most 2	37.49	63.88	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	4.99	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	0.01
	At most 1	92.62	107.35	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	30.96	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	0.96	3.95	17.15	0.96
	At most 6	0.60	3.84	0.44	0.60	3.841	0.43

Source: All the aforementioned measures were calculated using monthly time series data obtained from the sources listed in Table 3.1.

The results reported in Tables 3.26 and 3.29 to test the Johansen Cointegration, provide mixed results. There are five cointegrations equations (CEs) which are tested against one another at depicted in the Tables 3.26 and 3.29. Table 3.26 results indicate that the Trace & Maximum Eigenvalue values "at none" and "at most 1" are greater than their critical values in Gold (Australia and Japan), so we reject our Ho, indicating cointegration. However, because both (Trace & Maximum Eigenvalue) values are less than their critical value on the "at most" 2, 3, 4 and 5, we accept our Ho, indicating that there is no cointegration. Thus, the combined results of Gold Australia and Gold Japan suggest the existence of two cointegrating equations at the 0.05 level, and we apply Vector Error Correction Model (VECM) to find out the long-run causality between gold prices and macroeconomic factors. However, the TME values "at none" and "at most" 1, 2, 3, 4 and 5 are less than their critical values in Gold China and India, so we accept our Ho, indicating no cointegration and we apply Vector Autoregressive Regression (VAR) to capture the long-run relationship between gold prices and macroeconomic factors as they change over time.

Table 3.27 results show that the Trace & Maximum Eigenvalue values "at none" are greater than their critical values in Silver China and India, so we reject our Ho, indicating cointegration. However, because both (Trace & Maximum Eigenvalue) values are less than their critical value on the "at most 1, 2, 3, 4 and 5", we accept our Ho, indicating that there is no cointegration. Therefore, the combined results of Silver China and India suggest the existence of a single cointegrating equation at the 0.05 level, and we use the Vector Error Correction Model (VECM) to determine the long-run causal relationship between silver prices and macroeconomic variables.

Table 3.28 results depict that the Trace & Maximum Eigenvalue values "at none" and "at most 1" are greater than their critical values in Platinum USA, UK and China, so we reject our Ho, indicating cointegration. However, because both (Trace & Maximum Eigenvalue) values are less than their critical value on the "at most 2, 3, 4 and 5", we accept our Ho, indicating that there is no cointegration. Thus, the combined results of Platinum USA, UK and China indicate the existence of two cointegrating equations at the 0.05 level, and we apply Vector Error Correction Model (VECM) to find out the long-run causality between platinum prices and macroeconomic factors.

Table 3.29 suggested that the Trace & Maximum Eigenvalue values "at none" are greater than their critical values in Palladium Australia and United States, so we reject our Ho, indicating cointegration. However, because both (Trace & Maximum Eigenvalue) values are less than their critical value on the "at most 1, 2, 3, 4 and 5", we accept our Ho, indicating that there is no cointegration. Therefore, the combined results of Silver China and India suggest the existence of a single cointegrating equation at the 0.05 level, and we use the Vector Error Correction Model (VECM) to determine the long-run causal relationship between silver prices and macroeconomic variables.

3.4.3 Long-Run Relationship

After normalization, the first cointegrating vector on gold, silver, platinum, and palladium normalized cointegrating coefficients is estimated and reported in Tables 3.7, 3.8, 3.9, and 3.10 respectively.

Table 3.30: Normalized Cointegrating Coefficients – Gold

GOLD	CPI	IP	SP	SIR	LIR	UR
AUS	AUS	AUS	AUS	AUS	AUS	AUS
1.00	-12.43	N/A	1.60	-0.01	-1.78	-0.28
S.E	4.04	N/A	0.32	0.41681	0.55	0.44
GOLD	CPI	IP	SP	SIR	LIR	UR
JPN	JPN	JPN	JPN	JPN	JPN	JPN
1.00	-5534.05	1935.41	366.77	-	-	872.70
S.E	2270.59	395.07	144.69	10063.9	8759.25	285.73
t-value	-2.44	4.90	2.53	-3.07	-1.74	3.05
GOLD	CPI	IP	SP	IR	LIR	UR
CHN	CHN	CHN	CHN	CHN	CHN	CHN
1.00	-7.20	-0.18	-0.33	3.82	N/A	2.88
S.E	4.96	0.26	0.17	0.95	N/A	0.54
t-value	-1.45	-0.69	-1.94	4.02	N/A	5.33
GOLD	CPI	IP	SP	SIR	LIR	UR
IND	IND	IND	IND	IND	IND	IND
1.00	2.36	-3.90	0.28	-0.17	0.33	N/A
S.E	0.43	0.68	0.18	0.25	0.31	N/A
t-value	5.49	-5.74	1.55	-0.68	1.06	N/A

Table 3.31: Normalized Cointegrating Coefficients – Silver

SILVERCHN	CPI	IP	SP	IR	LIR	UR
	CHN	CHN	CHN	CHN	CHN	CHN
1.00	-41.77	0.25	-1.35	12.40	N/A	7.71
S.E	16.03	0.82	0.54	2.94	N/A	1.74
t-value	-2.60	0.30	2.5	4.22	N/A	4.43
SILVERIND	CPI	IP	SP	SIR	LIR	UR
	IND	IND	IND	IND	IND	IND
1.00	0.73	0.23	0.78	0.37	-0.43	N/A
S.E	0.57	1.05	0.18	0.23	0.26	N/A
t-value	1.28	0.22	4.33	1.61	-1.65	N/A

Table 3.32: Normalized Cointegrating Coefficients – Platinum

PLATINUM	CPI	IP	SP	SIR	LIR	UR
USA	USA	USA	USA	USA	USA	USA
1.00	-17.31	2.59	-1.17	-0.08	0.30	-1.10
S.E	2.96	0.70	0.30	0.05	0.14	0.27
t-value	-5.85	3.7	-3.9	-1.6	2.14	-4.07
PLATINUM	CPI	IP	SP	IR	LIR	UR
CHN	CHN	CHN	CHN	CHN	CHN	CHN
1.00	-0.29	-0.70	0.10	-1.83	N/A	-0.68
S.E	1.44	0.09	0.06	0.31	N/A	0.18
t-value	-0.20	-7.77	1.66	-5.90	N/A	-3.77
PLATINUM	CPI	IP	SP	SIR	LIR	UR
UK	UK	UK	UK	UK	UK	UK
1.00	-67.88	148.43	-4.89	-9.60	-3.14	5.87
S.E	12.00	30.91	4.30	1.95	3.16	4.18
t-value	-5.65	4.80	-1.14	-4.92	-0.99	1.40

Table 3.33: Normalized Cointegrating Coefficients - PALLADIUM

PALLADIUMAUS	CPI AUS	IP AUS	SP AUS	SIR AUS	LIR AUS	UR AUS
1.00	-1.55	N/A	-2.37	1.28	7.20	2.22
S.E	21.02	N/A	2.19	1.33	1.68	2.77
t-value	-0.07	N/A	-1.08	0.96	4.28	0.80
PALLADIUMUSA	CPI USA	IP USA	SP USA	SIR USA	LIR USA	UR USA
1.00	589.16	222.96	-253.92	-31.26	28.53494	N/A
S.E	230.31	81.65	41.74	7.29	18.96	N/A
t-value	2.56	2.73	-6.08	-3.45	1.50	N/A

Following is the normalised equation for gold, which was estimated as follows, and we used the same equation pattern to find the long-run relationship between dependent and independent variables using coefficients:

$$GOLD_{AUS} = 12.43CPI_{AUS} - 1.60SP_{AUS} + 0.01SIR_{AUS} + 1.78LIR_{AUS} + 0.28UR_{AUS} \quad \textit{Equation 21}$$

According to the normalized equation 21 Gold prices in Australia (GOLDAUS) demonstrated significantly positive relation with the Consumer Price Index Australia (CPIAUS), Short-term Interest Rate Australia (SIRAUS), Long-term Interest Rate Australia (LIRAUS) and Unemployment Rate Australia (URAUS) in the long run which suggested that gold market in Australia did provide hedge against inflation. Moreover, results revealed a long-run relationship between the price of gold in Australia and the short-term and long-term interest rates and unemployment rates. How- ever, the Gold Australia prices (GOLDAUS) showed a significantly negative relation- ship with the Share Price Australia (SPAUS) in the long run, which suggested that the gold market in Australia did not impact share prices.

Gold prices in Japan (GOLDJPN) had a significantly positive long-run relation- ship with the Consumer Price Index Japan (CPIJPN), the Short-term Interest Rate Japan (SIRJPN), and the Long-term Interest Rate Japan (LIRJPN), implying that the gold market in Japan, like the gold market in Australia, did provide a hedge against inflation. However, the gold prices of Japan (GOLDJPN) indicated a significantly negative relationship with the Industrial Production Japan (IPJAPN), Share Price Japan (SPJPN), and the Unemployment rate Japan (URJPN) in the long run, which suggested that the gold market in JAPAN did not impact on share prices and the Unemployment rate of Japan.

Gold prices in China (GOLDCHN) had a significantly positive long-run relationship with the Consumer Price Index China (CPICHN), the Industrial Production China (IPCHN), and the Share Price China (SPCHN), implying that the gold market in China, like the gold market in Japan and Australia, did provide a hedge against inflation. However, the gold prices of China (GOLDCHN) indicated a significantly negative relationship with the Interest Rate China (IRCHN) and Unemployment Rate China (URCHN), in the long run, which suggested that the gold market in China did not impact on Interest Rates and the Unemployment rates of China.

Gold prices in India (GOLDIND) had a significantly negative long-run relationship with the Consumer Price Index India (CPIIND), the Share Price India (SIRIND), and the Long-term Interest Rate India (LIRIND), implying that the gold market in India, did not provide a hedge against inflation and Share Price and long-term did not influence on the prices of gold in India. However, the gold prices of India (GOLDIND) indicated a significantly positive relationship with the Industrial Production Japan (IPIND) and the Share Price India (URIND) in the long run, which suggested that the gold market in India influenced from share prices and the Industrial Production of India as shown in equation 29.

Silver prices in China (SILVERCHN) had a significantly positive long-run relationship with the Consumer Price Index China (CPICHN) and the Share Price China (SPCHN), in the long-run implying that the silver market in China, did provide a hedge against inflation. However, the silver prices in China (GOLDCHN) indicated a significantly negative relationship with the Industrial Production (IPCHN), Interest Rate China (IRCHN) and Unemployment Rate China (URCHN), in the long run, which suggested that the silver market in China did not impact on Interest Rates and the Unemployment rates of China.

Silver prices in India (SILVERIND) had a significantly negative long run relationship with the Consumer Price Index India (CPIIND), the Industrial Production India (India), the Share Price India (SIRIND), and the Short-term Interest Rate India (LIRIND), implying that the gold market in India, did not provide a hedge against inflation in the long run and Share Price and short-term did not influence on the prices of gold in India. However, the silver prices in India (SILVERIND) indicated a significantly positive relationship with the Long-term interest rate India (LIRIND) in the long run, which suggested that the gold market in India influenced from share prices and the Industrial Production of India.

Platinum prices in USA (PLATINUMUSA) had a significantly positive long-run relationship with the Consumer Price Index USA (CPIUSA), the Share Price USA (SPUSA), the Short-term Interest Rate USA (SIRUSA) and the Unemployment Rate USA (URUSA), implying that the Platinum market in USA, did provide a hedge against inflation in the long run. Moreover, the Share Price, the Short-term interest rate and Unemployment Rate influenced on the prices of platinum in USA. However, the Platinum prices in USA (PLATINUMUSA) indicated a significantly negative relationship with the Industrial Production USA and the Long-term interest rate USA (LIRUSA) in the long run, which suggested that the Platinum market in USA did not influence from Industrial Production of USA and the Long-term Interest Rate USA.

Platinum prices in the China (PLATINUMCHN) had a significantly positive long-run relationship with the Consumer Price Index China (CPICHN), the Industrial Production China (IPCHN), the Interest Rate China (IRCHN) and the Unemployment Rate China (URCHN), implying that the Platinum market in China, did provide a hedge against inflation in the long run. Moreover, the Industrial Production, the Interest rate and Unemployment Rate influenced on the prices of platinum in China. However, the Platinum prices in China (PLATINUMCHN) indicated a significantly negative relationship with the Share Price China in the long run, which suggested that the Platinum market in China did not influence from Share Price of China.

Platinum prices in the UK (PLATINUMUK) had a significantly positive long-run relationship with the Consumer Price Index UK (CPIUK), the Share Price UK

(SPUK), the Short-term Interest Rate UK (SIRUK) and the Long-term Interest Rate UK (LIRUK), implying that the Platinum market in UK, did provide a hedge against inflation in the long run. Moreover, the Industrial Production, the Industrial Production UK and the Unemployment Rate UK influenced on the prices of platinum in UK. However, the Platinum prices in UK (PLATINUMUK) indicated a significantly negative relationship with the Industrial production and the Unemployment Rate in the UK in the long run, which suggested that the Platinum market in UK did not influence from Industrial Production and the Unemployment Rate of UK.

Palladium prices in the Australia (PALLADIUMAUS) had a significantly positive long-run relationship with the Consumer Price Index AUS (CPIAUS) and the Share Price AUS (SPAUS) implying that the Palladium market in the AUS, did provide a hedge against inflation in the long run. However, the Palladium prices in Australia (PALLADIUMAUS) indicated a significantly negative relationship with the Short-term and Long-term Interest Rates, the and the Unemployment Rate in the Australia in the long run, which suggested that the Palladium market in the Australia did not influence from the Short-term and Long-term Interest Rates, the and the Unemployment Rate of Australia.

3.4.4 Vector Error Correction Model (VECM) Results

An error correction model (ECM) is a single equation, but a VECM is multiple equation models based on a restricted variational analysis (VAR). Using the VECM approach, we first estimate each variable's long-run connection (using cointegration equation) and then estimate its short-run relationship (error correction equations). In comparison to VAR, VECM has the advantage of having more efficient coefficient estimates because the resulting VAR from VECM representation is more efficient than VAR. In addition to the ability to forecast more than one variable, VAR and VECM models can identify the interrelations between variables with each other (Shrestha and Bhatta, 2018). We observed that our variables in Tables 3.26, 3.27, 3.28, and 3.29 are cointegrated for Gold Japan & Australia, Silver India, Platinum UK, USA, China, and Palladium USA, respectively.

The Vector Error Correction Model (VECM) examines the dynamic relationships between macroeconomic variables and precious metals across developed and emerging markets.

The conclusions of Table 34 have been determined using several models. The VECM equation 30 for the dependent variable GOLD in the instance of Australia is as follows.

$$D(GOLD) = C(1) * (GOLD(-1) + 2.28 * SP_{AUS}(-1) + 3.76 * SIR_{AUS}(-1) - 9.98 * LIR_{AUS}(-1) + 2.78 \; URAUS(-1) - 0.03) + C(2)(CPI_{AUS}(-1) + 0.05 SP_{AUS}(-1) + 0.30 \; SIR_{AUS}(-1) - 0.66 \; LIR_{AUS}(-1) + 0.25 \; UR_{AUS}(-1) - 0.00) + 0.27) + C(3)D(GOLD(-1)) + C(4)D(GOLD(-2)) + C(5)D(GOLD(-3)) + C(6) \; D(CPI_{AUS}(-1)) + C(7)D(CPI_{AUS}(-2) + C(8)D(CPI_{AUS}(-3)) + C(9) \; D(SP_{AUS}(-1)) + C(10)D(SP_{AUS}(-2)) + C(11)D(SP_{AUS}(-3)) + C(12) \; D(SIR_{AUS}(-1)) + C(13)D(SIR_{AUS}(-2)) + C(14)D(SIR_{AUS}(-3)) + C(15) \; D(LIR_{AUS}(-1)) + C(16) \; D(LIR_{AUS}(-2)) + C(17)D(LIR_{AUS}(-3)) + C(18)D(UR_{AUS}(-1)) + C(19) \; D(UR_{AUS}(-2) + C(20) \; D(UR_{AUS}(-3) + C(21) \qquad \textit{Equation 22}$$

GOLD = Dependent variable

CPI, SP, SIR, LIR, UR= Independent variable

C (1) = Coefficient of cointegrating equation (long-term causality)

C (2) to C (20) = Coefficient of cointegrating equation (short-term causality)

C (21) = Constant / intercept.

Although the above equation could be split into 2x2 matrix as suggested by Tanna, Topaiboul and Li (2018); however, this approach is applied in one country context, Thailand, but this study considers seven countries and uses the six explanatory variables and four dependent variables. Therefore, application of this approach could be considered for an extended study.

From the VECM equation, the C(1) is the coefficient of cointegrating equation (GOLD(-1) + 2.28*SP____AUS_(-1) + 3.76*SIR____AUS_(-1) - 9.98*LIR____AUS_(-1) + 2.78*UR__AUS_ (-1) - 0.03) from which the residual is taken for developing the error correction (EC) term and from the EC term the long-run causality is developed. The results of the VECM model are presented in table 30. C (1) is the residual at a one-period lag of cointegrating vector between GOLD and CPI, SP, SIR, LIR, UR. In Australia, the ER term is negative (-0.02) and is highly significant at 5%, implying a long-run causality running from CPI, SP, SIR, LIR, and UR to GOLD. In other words, CPI, SP, SIR, LIR, and UR cause GOLD Australia in the long run. Since the ER term from the VECM is significant with negative signs, the Ho "no long-run causality between GOLD and CPI, SP, SIR, LIR, and UR is rejected. The result thus shows a long-run causality between CPI, SP, SIR, LIR, and UR to GOLD. However, in Japan, the ER term is negative (-0.01) and is insignificant at 5%, implying that there is no long-run causality running from CPI, IP, SP, SIR, LIR, and UR to GOLD. Since the ER term from the VECM is insignificant with a negative sign, the Ho "no long-run causality between GOLD and CPI, IP, SP, SIR, LIR, and UR is accepted. The result thus shows that the long-run causality between CPI, IP, SP, SIR, LIR, and UR to GOLD does not exist.

Similarly, we used the same approach for India, the USA, UK, and China. In India, the ER term is negative (-0.23) and is significant at 5%, implying a long-run causality running from CPI, IP, SP, SIR, and LIR to SILVER. Therefore, we reject our null hypothesis, i.e., Ho "no long-run causality between SILVER and CPI, IP, SP, SIR, and LIR. For Platinum, the ER terms are positive signs (1.00 & 0.06) and are highly significant at 5% in the UK and USA, respectively, which depicts that there is a long-run causality running from CPI, IP, SP, SIR, LIR, and UR to PLATINUM both in the UK and USA and the impact is positive between dependent and independent variables. However, in China the ER term for Platinum is negative (-0.25) and is marginally significant at 5%, indicating a long-run causality running from CPI, IP, SP, IR and UR to PLATINUM.

Table 3.34: Vector Error Correction Model Results

Metal	Gold				Silver		Platinum						Palladium	
Country	Australia		Japan		India		UK		USA		China		USA	
	Coefficient	*Prob.*	*Coefficient*	*Prob.*	*Coefficient*	*Prob.*	*Coefficient*	*Prob.*	*Coefficient*	*Prob.*	*Coefficient*	*Prob.*	*Coefficient*	*Prob.*
C(1)	-0.02	0.02 **	-0.01	0.50	-0.23	0.04**	1.00	0.00*	0.06	0.00 **	-0.25	0.05**	0.00	0.33
C(2)	0.28	0.01	-0.24	0.48	0.05	0.73	-0.01	0.86	-1.67	0.00	-0.66	0.45	-0.11	0.03
C(3)	0.03	0.57	-0.19	0.01	0.13	0.34	-1.18	0.05	-0.19	0.00	-0.05	0.56	0.04	0.44
C(4)	-0.03	0.54	-0.12	0.11	-0.64	0.55	1.12	0.06	0.08	0.21	-0.12	0.00	0.82	0.64
C(5)	-0.02	0.60	0.06	0.96	0.23	0.84	-0.07	0.82	0.03	0.97	-0.28	0.03	-4.69	0.01
C(6)	0.06	0.91	-2.06	0.09	0.26	0.62	-0.10	0.76	-1.45	0.05	-0.13	0.28	0.84	0.23
C(7)	1.21	0.02	-0.20	0.21	0.04	0.95	0.32	0.00	0.97	0.04	1.02	0.30	-0.29	0.69
C(8)	0.36	0.50	0.04	0.81	0.26	0.34	-0.28	0.00	0.84	0.07	0.15	0.87	0.35	0.01
C(9)	-0.01	0.84	0.02	0.83	-0.21	0.42	-0.14	0.02	0.24	0.02	0.16	0.21	0.31	0.04
C(10)	-0.01	0.89	-0.03	0.69	0.20	0.12	0.12	0.03	-0.01	0.92	0.07	0.48	-0.06	0.26
C(11)	-0.02	0.64	2.07	0.90	0.04	0.77	-0.01	0.84	-0.10	0.00	0.09	0.42	-0.02	0.64
C(12)	0.00	0.91	-3.81	0.82	0.24	0.50	0.03	0.58	-0.09	0.02	0.02	0.87	-0.09	0.22
C(13)	0.01	0.91	-1.05	0.78	-0.46	0.20	-0.10	0.63	-0.11	0.03	0.32	0.31	0.04	0.59
C(14)	-0.08	0.07	5.64	0.11	0.00	0.99	0.07	0.75	0.15	0.01	0.50	0.12	-0.14	0.31
C(15)	0.03	0.56	0.05	0.63	-	-	0.99	0.13	0.01	0.89	0.19	0.29	-0.15	0.27
C(16)	-0.04	0.51	-0.13	0.23	-	-	-	-	0.06	0.53	-0.08	0.68	0.01	0.08
C(17)	0.05	0.38	0.01	0.01	-	-	-	-	0.00	0.86	-0.01	0.18	-	-
C(18)	0.04	0.65	-	-	-	-	-	-	-	-	-	-	-	-
C(19)	0.09	0.32	-	-	-	-	-	-	-	-	-	-	-	-
C(20)	-0.11	0.22	-	-	-	-	-	-	-	-	-	-	-	-
C(21)	0.01	0.26	-	-	-	-	-	-	-	-	-	-	-	-
C(22)	0.00	0.92	-	-	-	-	-	-	-	-	-	-	-	-

Source: *Computed results based on secondary data compiled from IMF, OECD and The Global Company websites. ** indicate statistical significance at the 5% level and Long-Run Causality exist between Dependent & Independent Variable*

Additionally, we did not include the Short-Term Interest and Long-Term Interest variables in China due to a lack of data availability. As a result, we examined the impact on platinum prices in China using the total interest rate. On the other hand, the ER term for Palladium is positive (0.00) and is insignificant at 5%, depicting no long-run causality running from CPI, IP, SP, SIR, LIR and UR to PALLADIUM.

3.4.5 Wald Test Statistics

The Wald test (also known as the Wald Chi-Squared Test) is a method to determine whether or not explanatory variables in a model are significant. To examine the short-run causality between Dependent and Independent variables, we used the chi- square value of the Wald test (Banumathy and 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. For instance, CPI has lag 1 and lag 2 and CPI has 2 coefficients, C(4) and C(5). Therefore, the Null hypothesis. C (4) =C (5) =0. So we need to check the combination of these two coefficients is equal to zero or not. If they are 0, it means there is no short-run causality running from CPI to GOLD, etc.

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 3.35. We focus on the Null hypothesis and Chi-square value to examine that the Ho, i.e., C (4) = C (5) = 0 of lag two, cannot jointly influence the GOLD, SILVER, PLATINIUM, and PALLADIUM. According to the findings of the study, there is no short-run causality between the dependent variables (gold, silver, platinum, and palladium) and Independent variables (CPI, IP, SIR, LIR, UR), with the exception of the IP & Platinum, SIR & Platinum, LIR & Platinum, CPI & Palladium, SP & Palladium in the United States, IP & Gold in Japan, and SP & Platinum in the United Kingdom.

Table 3.35: Wald Test Statistics

Australia

	Null Hypothesis	Test Statistic	Value	Prob
CPI & Gold	Ho: C(6) =C(7)=C(8)0	**F-statistic**	1.87	0.13
		Chi-square	5.61	0.13
SP & Gold	Ho: C(9) =C(10)=C(11)=0	**F-statistic**	0.09	0.96
		Chi-square	0.28	0.96
SIR & Gold	Ho: C(12) =C(13)=C(14)=0	**F-statistic**	1.35	0.25
		Chi-square	4.05	0.25
LIR & Gold	H0: C(15) =C(16)=C(17)=0	**F-statistic**	0.44	0.72
		Chi-square	1.33	0.72
UR & Gold	H0: C(18) =C(19)=C(20)=0	**F-statistic**	1.04	0.37
		Chi-square	3.13	0.37

Japan

	Null Hypothesis	Test Statistic	Value	Prob
CPI & Gold	Ho: C(5) =C(6)=0	**F-statistic**	1.51	0.22
		Chi-square	3.02	0.22
IP & Gold	Ho: C(7) =C(8)=0	**F-statistic**	0.80	0.44
		Chi-square	1.60	0.44**
SP & Gold	Ho: C(9) =C(10)=0	**F-statistic**	0.09	0.90
		Chi-square	0.19	0.90
SIR & Gold	Ho: C(11) =C(12)=0	**F-statistic**	0.02	0.97
		Chi-square	0.05	0.97
LIR & Gold	Ho: C(13) +C(14)=0	**F-statistic**	0.83	0.36
		Chi-square	0.83	0.36
UR & Gold	Ho: C(15) =C(16)=0	**F-statistic**	1.06	0.35
		Chi-square	2.12	0.34

USA

	Null Hypothesis	Test Statistic	Value	Prob
CPI & Platinum	Ho: C(5) =C(6)=0	**F-statistic**	2.12	0.12
		Chi-square	4.25	0.11
IP & Platinum	Ho: C(7) =C(8)=0	**F-statistic**	3.32	0.03
		Chi-square	6.64	0.03**
SP & Platinum	Ho: C(9) =C(10)=0	**F-statistic**	2.80	0.06
		Chi-square	5.61	0 .06
SIR & Platinum	Ho; C(11) =C(12)=0	**F-statistic**	9.09	0.00
		Chi-square	18.17	0.00**
LIR & Platinum	Ho; C(13) =C(14)=0	**F-statistic**	4.78	0.00
		Chi-square	9.57	0.00**
UR & Platinum	Ho; C(15) =C(16)=0	**F-statistic**	0.19	0.82
		Chi-square	0.39	0.82
CPI & Palladium	Ho: C(4) =C(5)=0	**F-statistic**	4.12	0.02
		Chi-square	8.23	0.02**
IP & Palladium	Ho: C(6) =C(7)=0	**F-statistic**	0.83	0.44
		Chi-square	1.66	0.43
SP & Palladium	Ho: C(8) =C(9)=0	**F-statistic**	6.53	0.00
		Chi-square	13.06	0.00**
SIR & Palladium	Ho; C(10) =C(11)=0	**F-statistic**	1.00	0.37
		Chi-square	2.00	0.37
LIR & Palladium	Ho; C(12) =C(13)=0	**F-statistic**	0.78	0.46
		Chi-square	1.55	0.46
UR & Palladium	Ho; C(14) =C(15)=0	**F-statistic**	0.93	0.39
		Chi-square	1.87	0.39

Source: *Computed results based on secondary data compiled from IMF, OECD and The Global Company websites. ** indicate statistical significance at the 5% level and Short-Run Causality exists between Dependent & Independent Variables.*

India

	Null Hypothesis	Test Statistic	Value	Prob
CPI & Silver	Ho: C(4) =C(5)=0	**F-statistic**	0.19	0.82
		Chi-square	0.38	0.83
IP & Silver	Ho: C(6) =C(7)=0	**F-statistic**	0.14	0.87
		Chi-square	0.28	0.87
SP & Silver	Ho: C(8) =C(9)=0	**F-statistic**	0.67	0.51
		Chi-square	1.34	0.51
SIR & Silver	Ho: C(10) =C(11)	**F-statistic**	0.73	0.40
		Chi-square	0.73	0.40
LIR vs Silver	Ho: C(12) =C(13)	**F-statistic**	1.43	0.24
		Chi-square	1.43	0.23

UK

	Null Hypothesis	Test Statistic	Value	Prob
CPI & Platinum	Ho: C(3) =C(4)=0	**F-statistic**	2.19	0.11
		Chi-square	4.37	0.11
IP & Platinum	Ho: C(5) =C(6)=0	**F-statistic**	0.52	0.60
		Chi-square	1.03	0.60
SP & Platinum	Ho: C(7) =C(8)=0	**F-statistic**	7.50	0.00
		Chi-square	15.00	0.00**
SIR & Platinum	Ho; C(9)=C(10)=0	**F-statistic**	2.67	0.07
		Chi-square	5.34	0.07
LIR & Platinum	Ho; C(11) =C(12)=0	**F-statistic**	0.69	0.50
		Chi-square	1.39	0.5
UR & Platinum	Ho; C(13) =C(14)=0	**F-statistic**	1.14	0.32
		Chi-square	2.27	0.32

China

	Null Hypothesis	Test Statistic	Value	Prob
CPI & Platinum	Ho: C(7) =C(8)=0	**F-statistic**	0.55	0.58
		Chi-square	1.10	0.58
IP & Platinum	Ho: C(9)=C(10)=0	**F-statistic**	0.87	0.42
		Chi-square	1.74	0.42
SP & Platinum	Ho: C(11) =C(12)=0	**F-statistic**	0.35	0.70
		Chi-square	0.70	0.70
IR & Platinum	Ho; C(13) =C(14)=0	**F-statistic**	1.61	0.21
		Chi-square	3.21	0.20
UR & Platinum	Ho; C(15) =C(16)=0	**F-statistic**	0.58	0.56
		Chi-square	1.15	0.56

Source: *Computed results based on secondary data compiled from IMF, OECD and The Global Company websites. ** indicate statistical significance at the 5% level and Short-Run Causality exists between Dependent & Independent Variables.*

3.4.6 Vector Auto Regression Model (VAR) Results

Table 3.36 presents results based on the vector autoregressions (VAR) for monthly log prices for Gold China and India and Palladium Australia. As discussed in section 3.4.2, if the trace and maximum eigenvalue values "at none" and "at most"1, 2, 3, 4 and 5 are less than their critical values, as they are in Gold (China and India) and Palladium Australia, we accept our Ho, indicating that there is no cointegration. Therefore, to capture the long-run relationship between gold prices and macroeconomic variables as they change over time, we used Vector Autoregressive Regression (VAR). The VAR equation 23 model for the dependent variable GOLD in the instance of China is as follows.

$$GOLD = C(1) * GOLD(-1) + C(2) * GOLD(-2) + C(3) * CPICHN(-1) + C(4) * CPICHN(-2) + C(5) * IPCHN(-1) + C(6) * IPCHN(-2) + C(7) * SPCHN(-1) + C(8) * SPCHN(-2) + C(9) * IRCHN(-1) + C(10) * IRCHN(-2) + C(11) * URCHN(-1) + C(12) * URCHN(-2) + C(13) \quad \text{Equation 23}$$

GOLD = Dependent variable

CPI, IP, SP, IR, UR= Independent variable

C (1) = Coefficient of cointegrating equation (long-term causality)

C (2), C (3), C (4), C (5), C (6), C (7), C (8), C (9), C (10), C (11), C (12) = Coefficient of cointegrating equation (short-term causality)

C (13) = Constant / intercept

It is also suggested by Toda and Yamamoto, (2018) that the causality tests can also be conducted in the VAR framework without cointegration through augmenting the VAR model as discussed in detail by Tanna et al. (2018).

Thus, the results of Table 2 reveals that a long-term relationship exists between GOLD China and CPI, IP, SP, IR, UR, GOLD India and CPI, IP, SP, SIR, and LIR, and PALLADIUM Australia and CPI, IP, SP, SIR, LIR, and UR.

Table 2.36: Vector Auto Regression Model Results

Metal	Gold				Palladium	
Country	China		India		Australia	
	Coefficient	*Prob.*	*Coefficient*	*Prob.*	*Coefficient*	*Prob.*
C(1)	0.73	0.00**	0.65	0.00**	0.88	0.00**
C(2)	0.16	0.11	0.03	0.83	1.18	0.45
C(3)	0.82	0.41	0.12	0.86	0.00	0.99
C(4)	-1.66	0.08	-0.30	0.66	0.06	0.52
C(5)	-0.08	0.36	-0.01	0.99	0.12	0.30
C(6)	0.03	0.68	0.34	0.31	-0.17	0.51
C(7)	-0.18	0.03	0.01	0.97	0.10	0.11
C(8)	0.17	0.03**	-0.08	0.61	-2.42	0.12
C(9)	-0.51	0.04**	-0.02	0.82	0.04	0.85
C(10)	0.21	0.39	-0.14	0.15	-0.04	0.67
C(11)	-0.12	0.42	0.10	0.68	-0.16	0.21
C(12)	-0.13	0.40	0.00	1.00	0.22	0.37
C(13)	5.73	0.01**	3.50	0.00**	-0.07	0.84

Source: *Computed results based on secondary data compiled from IMF, OECD and The Global Company websites. ** indicate statistical significance at the 5% level and Long-Run Causality exist between Dependent & Independent Variable*

3.4.7 Autoregressive Distributed Lag Approach Results

Long-Run Relationship - ARDL Bound Testing The results of the unit root test are not consistent in Gold (Switzerland, UK, USA and Mexico), Silver (USA, UK, Switzerland, China and Mexico) and Platinum (Australia), as our variables are found to be a mixture of I(0) and I(1), and the results show different results in each test as shown in 3.17, 3.18 and 3.22. Therefore, we decided to use the Autoregressive Distributed Lag Approach (ARDL) technique or ARDL Bound Testing to capture the long-run relationship among the dependent and independent variables.

In Table , ECM's representation for the ARDL approach is selected using the AIC criterion. To examine the long-run relationship among the variables, we use the ARDL bound testing where our ''Null hypothesis is H_0: No long-run relationship exists. Secondly, we observe the F-statistics value, and the rule is that if the F-statistics value is greater than I(1) bound, then our alternate hypothesis would be accepted, which H_1:

There is a long-run relationship exist between the variables. In addition, if our F-statistic value is less than the I(0) Bound test, then our null hypothesis is accepted, which means no long-run relationship exists between dependent and independent variables. Thirdly, If the F-statistics value lies between I(0) Bound and I(1) Bound, then it means our results are inconclusive, and no relationship exists. The findings show that there is no long-run relationship exists between the dependent and Independent variables in Gold (UK, USA, Switzerland, Mexico), Silver (UK, USA, Switzerland, Mexico and China), and Platinum (Australia).

Table 3.37: Long-Run ARDL Results - Bound Test

Variable	Significance	I(0) Bound	I(1) Bound	F-statistics	Outcome
Gold UK	10%	2.12	3.23	0.38	No Long-Run Relationship
	5%	2.45	3.61		
Gold USA	10%	2.03	3.23	1.10	No Long-Run Relationship
	5%	2.32	3.61		
Gold Switzerland	10%	2.26	3.35	2.77	No Long Run Relationship
	5%	2.62	3.79		
Gold Mexico	10%	2.12	3.23	2.50	No Long-Run Relationship
	5%	2.45	3.61		
Silver UK	10%	2.03	3.13	1.05	No Long-Run Relationship
	5%	2.32	3.5		
Silver USA	10%	2.12	3.23	2.10	No Long-Run Relationship
	5%	2.45	3.61		
Silver Switzerland	10%	2.26	3.35	2.98	No Long-Run Relationship
	5%	2.62	3.79		
Silver Mexico	10%	2.26	3.35	2.70	No Long-Run Relationship
	5%	2.62	3.79		
Silver China	10%	2.26	3.35	2.50	No Long-Run Relationship
	5%	2.62	3.79		
Platinum Australia	10%	2.26	3.35	2.75	No Long-Run Relationship
	5%	2.62	3.79		

Source: *Computed results based on secondary data compiled from IMF, OECD and The Global Company websites. ** indicate rejecting the null at the 10% level, the value of F-statistics for the above variable is more than upper bound 3.77, hence we reject the null hypothesis at 10% level.*

Short- Run Relationship - Wald Test Statistics: Table 3.38 demonstrates no short-run causal relationship between dependent and independent variables in the GOLDUK and SILVERUK, except for long-term interest rates. However, there is a short-run causal relationship between short-term and long-term interest rates and the US gold price. In case of SILVER USA, the short run causality exist from SIR and UR to the price of SILVER. Furthermore, we found no evidence of short-run causality between the CPI, SP, SIR, LIR, and UR and gold prices in Switzerland, but in case of SILVER, there is a short-run causality from SP to SILVER prices. In the instance of Mexico, there is a short-run causal relationship between CPI and gold prices. In China, no short-run causal relationship between SILVER prices and independent variables. Table 3.39 indicates a short-run causality from CPI, SP and UR to the prices of PLATINUM in Australia. Similarly, Silver in Mexico, we found no short-run causality from CPI, IP, SP, SIR and UR to the prices of SILVER in Mexico.

Table 3.38: Short- Run ARDL Results - WALD Test - Gold

UK					USA				
	Null Hypothesis	***Test Statistic***	***Value***	***Prob***		***Null Hypothesis***	***Test Statistic***	***Value***	***Prob***
GOLD	Ho: C(1)=C(2)=C(3)=0	**F-statistic**	2652.50	0.00	**GOLD**	Ho: C(1)=0	**F-statistic**	15048.87	0.00
		Chi-square	7,957.51	0.00**			**Chi-square**	15048.87	0.00**
CPI	Ho: C(4)=C(5)=C(6)=C(7)=0	**F-statistic**	1.56	0.18	**CPI**	Ho: C(2)=C(3)=C(4)=0	**F-statistic**	4.50	0.00
		Chi-square	6.25	0.18			**Chi-square**	13.48	0.00**
IP	Ho: C(8)=0	**F-statistic**	1.49	0.22	**IP**	Ho: C(5)=0	**F-statistic**	3.24	0.07
		Chi-square	1.49	0.22			**Chi-square**	3.24	0.07
SP	H0: C(9)=C(10)=0	**F-statistic**	1.39	0.72	**SP**	Ho: C(6)=C(7)=0	**F-statistic**	1.86	0.16
		Chi-square	2.78	0.72			**Chi-square**	3.71	0.16
SIR	H0: C(11)=C(12)=0	**F-statistic**	1.00	0.37	**SIR**	Ho: C(8)=C(9)=0	**F-statistic**	3.71	0.02
		Chi-square	2.00	0.37			**Chi-square**	7.43	0.02**
LIR	H0: C(13)=C(14)=C(15)=C(16)=0	**F-statistic**	6.15	0.00	**LIR**	Ho: C(10)=C(11)=C(12)=0	**F-statistic**	5.67	0.00
		Chi-square	24.60	0.0**			**Chi-square**	17.03	0.00**
UR	H0: C(17)=C(18)=0	**F-statistic**	2.58	0.07	**UR**	Ho: C(13)=0	**F-statistic**	0.16	0.68
		Chi-square	5.17	0.07			**Chi-square**	0.16	0.68

Switzerland					Mexico				
	Null Hypothesis	***Test Statistic***	***Value***	***Prob***		***Null Hypothesis***	***Test Statistic***	***Value***	***Prob***
GOLD	Ho: C(1)=C(2)=0	**F-statistic**	4192.38	0.00	**GOLD**	Ho: C(1)=C(2)=C(3)=C(4)=0	**F-statistic**	50.04	0.00
		Chi-square	8384.77	0.00**			**Chi-square**	200.18	0.00**
CPI	Ho: C(3)=0	**F-statistic**	0.02	0.88	**CPI**	Ho: C(5)=C(6)=C(7)=0	**F-statistic**	5.20	0.00
		Chi-square	0.02	0.88			**Chi-square**	15.60	0.00**
SP	Ho:C(4)=C(5)=0	**F-statistic**	2.69	0.06	**IP**	Ho: C(8)=0	**F-statistic**	1.48	0.22
		Chi-square	5.38	0.06			**Chi-square**	1.48	0.22
SIR	Ho: C(6)=C(7)=C(8)=0	**F-statistic**	2.09	0.1	**SIR**	Ho: C(9)=0	**F-statistic**	2.68	0.10
		Chi-square	6.27	0.09			**Chi-square**	2.68	0.1
LIR	Ho: C(9)=0	**F-statistic**	3.88	0.04	**UR**	Ho; C(10)=0	**F-statistic**	1.01	0.31
		Chi-square	3.88	0.04			**Chi-square**	1.01	0.31
UR	Ho: C(10)=C(11)=C(12)=0	**F-statistic**	2.48	0.06	-	-	-	-	-
		Chi-square	7.43	0.06					

Table 3.39: Short- Run ARDL Results - WALD Test – Silver

UK					USA				
	Null Hypothesis	*Test Statistic*	*Value*	*Prob*		*Null Hypothesis*	*Test Statistic*	*Value*	*Prob*
SILVER	Ho: C(1)=C(2)=C(3)=0	**F-statistic**	2652.50	0.00	**SILVER**	Ho: C(1)=C(2)=C(3)=C(4)=0	**F-statistic**	1759.79	0.00
		Chi-square	7,957.51	0.00**			**Chi-square**	7039.165	0.00**
CPI	Ho: C(4)=C(5)=C(6)=C(7)=0	**F-statistic**	1.56	0.18	**CPI**	Ho: C(5)=0	**F-statistic**	1.89	0.17
		Chi-square	6.25	0.18			**Chi-square**	1.89	0.17
IP	Ho: C(8)=0	**F-statistic**	1.49	0.22	**IP**	Ho: C(6)=0	**F-statistic**	0.25	0.61
		Chi-square	1.49	0.22			**Chi-square**	0.25	0.61
SP	H0: C(9)=C(10)=0	**F-statistic**	1.39	0.72	**SP**	Ho: C(7)=C(8)=0	**F-statistic**	2.70	0.07
		Chi-square	2.78	0.72			**Chi-square**	5.41	0.07
SIR	H0: C(11)=C(12)=0	**F-statistic**	1.00	0.37	**SIR**	Ho: C(9)=0	**F-statistic**	4.41	0.04
		Chi-square	2.00	0.37			**Chi-square**	4.41	0.04**
LIR	H0: C(13)=C(14)=C(15)=C(16)=0	**F-statistic**	6.15	0.00	**LIR**	Ho: C(10)=C(11)=C(12)=C(13)=0	**F-statistic**	2.13	0.08
		Chi-square	24.60	0.0**			**Chi-square**	8.53	0.07
UR	H0: C(17)=C(18)=0	**F-statistic**	2.58	0.07	**UR**	Ho: C(14)=C(15)=0	**F-statistic**	4.29	0.01
		Chi-square	5.17	0.07			**Chi-square**	8.58	0.01**

Switzerland					China				
	Null Hypothesis	*Test Statistic*	*Value*	*Prob*		*Null Hypothesis*	*Test Statistic*	*Value*	*Prob*
SILVER	Ho: C(1)=C(2)=C(3)=0	**F-statistic**	2589.00	0.00	**SILVER**	Ho:C(1)=0	**F-statistic**	328.68	0.00
		Chi-square	7767.01	0.00**			**Chi-square**	328.68	0.00**
CPI	Ho:C(4)=C(5)=0	**F-statistic**	2.29	0.10	**CPI**	Ho: C(2)=C(3)=C(4)=0	**F-statistic**	2.22	0.09
		Chi-square	4.58	0.10			**Chi-square**	6.65	0.08
SP	Ho:C(6)=C(7)=C(8)=C(9)=0	**F-statistic**	3.04	0.01	**IP**	Ho: C(5)=0	**F-statistic**	0.23	0.62
		Chi-square	12.18	0.01**			**Chi-square**	0.23	0.62
SIR	Ho: C(10)=C(11)=0	**F-statistic**	2.51	0.08	**SP**	Ho: C(6)=C(7)=0	**F-statistic**	2.62	0.07
		Chi-square	5.03	0.08			**Chi-square**	5.25	0.07
LIR	Ho: C(12)=0	**F-statistic**	0.01	0.93	**IR**	Ho: C(8)=C(9)=0	**F-statistic**	1.37	0.25
		Chi-square	0.01	0.93			**Chi-square**	2.75	0.25
UR	Ho: C(13)=C(14)=C(15)=0	**F-statistic**	1.39	0.24	**UR**	Ho; C(10)=C(11)=0	**F-statistic**	2.33	0.10
		Chi-square	4.18	0.24			**Chi-square**	4.66	0.09

Mexico					Australia				
	Null Hypothesis	*Test Statistic*	*Value*	*Prob*		*Null Hypothesis*	*Test Statistic*	*Value*	*Prob*
SILVER	Ho: C(1)=0	**F-statistic**	1210.044	0.00	**PLATINUM**	Ho: C(1)=C(2)=0	**F-statistic**	1259.59	0.00
		Chi-square	1210.044	0.00**			**Chi-square**	2519.19	0.00**
CPI	Ho: C(2)=C(3)=0	**F-statistic**	2.29	0.04	**CPI**	Ho:C(3)=0	**F-statistic**	7.39	0.01
		Chi-square	4.58	0.04**			**Chi-square**	7.39	0.01**
IP	Ho: C(4)=0	**F-statistic**	0.60	0.43	**SP**	Ho:C(4)=C(5)=C(6)=C(7)=0	**F-statistic**	3.04	0.01
		Chi-square	0.60	0.43			**Chi-square**	12.18	0.01**
SP	Ho: C(5)=0	**F-statistic**	4.63	0.03	**SIR**	Ho: C(8)=0	**F-statistic**	1.49	0.22
		Chi-square	4.63	0.03			**Chi-square**	1.49	0.22
SIR	Ho: C(6)=0	**F-statistic**	1.21	0.27	**LIR**	Ho: C(9)=0	**F-statistic**	2.36	0.12
		Chi-square	1.21	0.26			**Chi-square**	2.36	0.12
UR	Ho: C(7)=0	**F-statistic**	2.39	0.12	**UR**	Ho: C(10)=0	**F-statistic**	8.57	0.00
		Chi-square	2.39	0.12			**Chi-square**	8.57	0.00**

Source: *Computed results based on secondary data compiled from IMF, OECD and The Global Company websites. ** indicate statistical significance at the 5% level and short-run causality exist between dependant and Independent Variables*

3.5 Conclusion.

The present study investigated the long-run and short-run relationship between prices of 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) using various cointegration techniques. 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 study considered the monthly closing prices of precious metals and CPI, IP, SP, LIR, SIR, and UR from January 1979 to September 2020, including 501 maximum and 85 minimum monthly time series observations due to the absence of data for different countries before and after the sample period. The unit root features of the series with and without breaks demonstrate the series' level non-stationarity. By examining the number of cointegrating equations between the variables, the Johansen Trace test with and without breaks, the ARDL model, and the Wald test was used to find the long- and short-run relationships. The appearance of the results varies between experiments, as breaks might skew the utility of typical statistical methodologies.

The findings demonstrate cointegrating correlations between monthly prices of precious metals and the CPI, IP, SP, LIR, SIR, and UR over the last forty years, using various econometric tests. The cointegrating correlations in the long run and short run, on the other hand, are highly unstable and vary between developed and emerging economies, showing several structural breaches in the cointegrating relationships during periods of inflation, financial crises, and recession. The VECM, VAR, and ARDL Bound testing were used to capture the long-run relationship among the dependent and independent variables. The current study's findings revealed a long-run causal relationship was found between the prices of gold in Australia, China, India, and Switzerland; silver in India; platinum in the United States, the United Kingdom, and China; and palladium in Australia. However, the gold markets in the United Kingdom, the United States, and Mexico, the silver markets in the United States, the United Kingdom, Switzerland, Mexico, and China, and the platinum market in Australia did not result in any long-term relationships between developed and emerging market economies.

The Wald test was used to determine whether explanatory variables in a model are significant and examine the short-run causality between Dependent and Independent variables. For this purpose, the Wald test was applied as it predicts short-run causality between dependent and some independent variables, especially in developed economies, as illustrated in Table . For instance, Gold Japan and Platinum USA have a short-run causality running from Industrial Production (IP) to Gold and Platinum as both metals have a high demand in electronics, computers, dentistry, jewelry medicine, and much more. When the demand for gold in any of these industries fluctuates, it will impact the price of gold. Moreover, the USA auto industry alone would use 48% of global platinum production, and the impact of additional demand on platinum prices would add to the challenge of lowering car costs.

To explore the short-run inflation hedging ability of precious metals, this study further revealed that Gold USA, Mexico, and Platinum Australia indicate the short-run causality running from a CPI to Gold and Platinum. These findings show that gold could outperform traditional assets in an inflationary scenario because it is durable, relatively transportable, universally acceptable, and easily authenticated. However, this study found no short-run relationship between precious metals and independent variables in other developed and emerging economies. Furthermore, the short-run causality between short-term and long-term interest rates and gold, silver, and platinum is exclusively observed in the United Kingdom. These findings imply that portfolio managers in the United Kingdom have a greater opportunity to invest in precious metals such as gold, silver, and platinum than in palladium to limit risk during difficult times. Overall, the findings of this study imply that macroeconomic fundamentals provide critical insight into the price link between precious metals and that investors may use precious metals differently during periods of economic distress.

4 Chapter 4: Macroeconomic determinants of Precious Metals Prices: Panel data Evidence (Paper 3)

Abstract

This paper investigates the combined effect of macroeconomic factors on the pricing of precious metals in developed and emerging economies. We use the panel least squares estimation, a fixed-effects model, and a random-effects model since it accounts for variable heterogeneity across precious metals and countries over time. We also employ a dynamic two-step generalized method of moments (GMM) estimators to improve the robustness and ascertain the consistency of the results. The data set covers 1979–2020 for five developed and emerging economies. Our findings demonstrate that the prices of precious metals fluctuate in response to changes in macroeconomic factors across developed and emerging economies. The findings of the study have significant policy ramifications. The major macroeconomic indicators used in this study can help forecast precious metals' returns in developed and emerging economies. These findings support the use of gold, silver, and platinum investments as inflation hedges, and they may assist gold mining enterprises in reaching low-income and rural populations to determine the unemployment rate. The central banks of these five countries should ensure that the above macroeconomic factors do not disproportionately affect precious metals returns.

Keywords: Precious Metals prices; Macroeconomic factors; Financial Crisis; USA, UK, Japan, China, and India

4.1 Introduction

The purpose of this study is to investigate the combined effect of macroeconomic factors on the pricing of three precious metals (gold, silver, and platinum) across developed and emerging economies. This study takes into consideration six macroeconomic variables - Consumer Price index (CPI), Industrial Production (IP), Share Price (SP), Short-term Interest Rate (SIR), Long-term Interest Rate (LIR) and the Unemployment Rate (UR). The volatility of precious metals prices, especially during turbulent times, is the motivator for this research. Macroeconomic management is difficult due to financial instability threats. In such a case, a well-defined portfolio diversification strategy can mitigate the external economic risks associated with the volatility of metal prices (Pradhan et al., 2020).

The macroeconomic environment appears to influence both precious metals and stock markets, as it can potentially cause contagious effects (crises) that lead to more significant correlations between global equity markets, especially in periods of high and extreme volatility, reducing the diversification benefits of traditional stock investments (Chan-Lau et al., 2004; Diamandis, 2009). Additionally, such global contagion effects encourage investors to pursue alternative investment instruments as a component of diversified portfolios to hedge against rising stock market risk.

From January 1987 to December 2010, the correlation between commodities (agricultural, metal, and energy products) and more traditional assets was historically low. For instance, the correlation between West Texas Intermediate (WTI) and the S&P 500 averaged 3%, whereas the correlation between gold and US government bonds rounded to 0% Chevallier et al. (2014). In contrast with this view, it appears that since 2008, these correlation levels have been changing dramatically. Precious metal prices have risen to record highs, and the growing interconnectedness of major stock markets has sparked interest in analysing precious metals price transmission across markets. Growing innovation and greater use of precious metals for such purposes have led to their greater demand. Finally, the metallurgical and jewellery industries have expanded and have also led to increasing interest in the precious metal markets (Edwards and Caglayan, 2001).

Moreover, Lee and Lin (2010) also observed the surge in the prices of precious metals between 1991 and 2011. In addition to the mentioned points above, there are numerous factors that contributed to these soaring prices, including rising inflationary expectations, the financial-economic crisis of 2007-08, and increased demand from emerging markets. Due to these significant external shocks that have led to changes in the gold and silver markets, investors' curiosity has been piqued, as both precious metals serve as significant stores of value and contribute to risk diversification by diversifying their portfolios (Adrangi et al., 2003a; Lucey and Tully, 2006). Furthermore, arbitrageurs and speculators pay special attention to the spillover effects between gold and silver markets, which can be seen across other asset markets such as stocks, foreign exchange markets and different economies. Investment in precious metals has increased significantly because of the stock market crash of 2000, increased international integration of the stock and bond markets, and increased participation by institutional investors. As a result, precious metal prices have increased due to the increase in investor participation in precious metal markets (Edwards and Caglayan, 2001).

Precious metals prices rose significantly, from $350 to $1300 an ounce in January 2003; the increase could be attributed to the financial credit crisis (Figuerola-Ferretti and McCrorie, 2016). The move away from financial markets to precious metals was to diversify stock market risk. The silver and platinum prices followed a similar pattern, and they also experienced a significant rise in their prices, from approximately $5 and $600 per ounce in January 2003. By 2010, their values had risen from $19 and $1700, respectively, as a result of the global demand for precious metals (Rubbaniy et al., 2011). The changes also observed in precious metals are affected by external shocks, for example because of COVID-19. The price of precious metals has risen to an all-time high of US$1,902/toz on July 24, 2020 (Mokni et al., 2021) and evidencing substitution effect and risk diversification strategies employed by investors. Throughout the epidemic, the price of gold prices continued to rise steadily, while silver and platinum prices followed a similar pattern, although at a slower pace (Ezeaku et al., 2021). These upward price trends entice investors to invest their money into these metals.

The trend in precious metal prices suggests their prices are affected by micro and macroeconomic factors: excavation processes, economic and political shocks. Therefore, this study sets out to evaluate the relationships between precious metals, capital markets and their inclusion in portfolio to diversify risk. The literature on the precious metals markets places particular emphasis on three aspects: i) how precious metal prices react to changing economic situations (Frankel and Hardouvelis, 1985; Cornell and French, 1986; Christie-David et al., 2000; Lucey and O'Connor, 2016); (ii) the predictability of precious metals prices mainly gold and silver (Miffre and Rallis,2007; Auer,2016); and (iii) to investigate the causal relationship between gold and silver prices (Wahab et al., 1994; Hillier et al., 2006; Pierdzioch et al., 2015; Zhu et al., 2016; Schweikert, 2018).

However, a few studies have examined the significance of precious metals, such as investigating the factors that determine the price of gold (Levin and Wright, 2006); gold as a safe haven for investments (Hood and Malik, 2013; Shahbaz et al., 2014; Walczak-Gańko, 2016); investing in gold as a form of hedging against the risk of inflation (Ranson, 2005; Shahbaz et al., 2014) as well as the purchase of gold as an investment to protect against fluctuations in exchange rates (Capie et al., 2004). As a result, the vast majority of the previous research only focuses on the gold and silver market and ignores the markets for the other precious metals (Pradhan et al., 2020).

Thus, the study aims to contribute to the existing literature by investigating whether macroeconomic factors of the United States of America, the United Kingdom, Japan, China, and India would play a recurring and significant role in determining precious metals - gold, silver and platinum prices using a panel data regression model. The rationale for considering the cross-country context and estimating the combined relationship is to examine the linkages between macroeconomic events in different countries and the resulting impact on precious metals prices and volatility. Moreover, this study examines whether macroeconomic factors impact the pricing of precious metals globally. The explanatory variables employed in this study lend themselves to changes in the macroeconomic environment, government policies and external shocks. Therefore, financial studies have used macroeconomic variables to predict precious metals prices (Levin and Wright, 2006).

The innovative feature for choosing precious metals and to use this model is to take both time and cases simultaneously. However, other models are constrained in that they can only reflect heterogeneities between units or overtime in one or the other direction. Moreover, panel data models outperform other methods when it comes to capturing heterogeneity in both cross-sectional units and time dimensions, and they are better suited to studying the dynamics of change as well as complex behavioural models than other methods when it comes to reducing estimation bias and multicollinearity (Baltagi et al., 2005; Wooldridge, 2010).

The "Hausman test" is also used to distinguish between fixed and random effects in a situation. As a result, it is decided that the fixed effect definition should be utilised for a few valuable metals, while the random specification should be used for others (Esarey and Jaffe, 2017). To take account of variations and test for the robustness, the study employed a dynamic panel data estimator, also known as a generalised method of moments (GMM) estimator, is also used to improve the robustness of the results (Arellano and Bond, 1991; Blundell and Bond, 1998, 2000). The outcomes of this study indicate that the macroeconomic factors of the United States of America, the United Kingdom, Japan, China, and India do have significant impact on gold silver and platinum prices. Moreover, the findings suggest that the prices of precious metals fluctuate in response to changes in macroeconomic factors.

The conclusion of this study are significant for international investors seeking to diversify their portfolios, as precious metals may act as a hedge against inflation. Moreover, the findings have established the relationship between precious metal prices and macroeconomic variables (Apergis et al., 2014a). When building investment plans and contemplating the inclusion of precious metals into portfolio composition, investors will find this study insights to be extremely beneficial. However, this study is characterized with some limitations.

The first limitation of this study is the period covered by the data, namely 1979–2020, for this duration there is limited availability of data for multiple sources. This study has focused on the data collected monthly. However, to test the sensitivity to different time frame, it is suggested that future research may replicate this study using different sampling period, such as weekly or daily data, an approach that was not possible for this study due to time and access to data.

The second limitation of this study is that our data set only covers the prices of three precious metals, namely gold, silver, and platinum, but to increase the range of metals, the researcher might include palladium to test its relevance in the family of precious metals.

The third limitation of this study is that it looked at the aggregated data and studied the combined effect of macroeconomic factors on the prices of three precious metals (gold, silver, and platinum) in developed and emerging economies. To overcome this limitation, the individual impact of macroeconomic factors on the pricing of four precious metals (gold, silver, platinum, and palladium) in developed and emerging economies is investigated in greater depth, explored, and addressed in detail in chapter 5 of this thesis.

The remainder of the study sections are organized as follows; Section 4.2 provides an in-depth consideration of the literature, while the section 4.3 evaluates and describes the techniques employed in this study. Section 4.4 discusses and evaluates the data collection approach employed and tests the suitability of the data, conducts some preliminary tests, and concludes with presenting empirical findings. Section 4.5 brings together the empirical and theoretical perspectives and discusses the findings and policy implications for three precious metals.

4.2 Literature Review

There is considerable literature (Vigne et al., 2017; O'Connor et al., 2015; Hussainey et al., 2009; Gan et al., 2006) that have examined the importance of macroeconomic variables and concluded that macroeconomic variables are recognized as significant drivers of asset prices, they are intrinsically linked with assets underlying values. It is proved and tested that asset prices respond to economic events (Ewing et al., 2003) in the times of crisis and due to economic shocks, like the oil shock or economic structural adjustment. However, the degree of the impact of the shock varies due to correlation between the assets and the ensuing event. Some macroeconomic events have a more substantial impact on asset prices than others as they are more closely related with macroeconomic factors, while others have no effect.

As we enter the twenty-first century, extreme events are growing more common, and geopolitical concerns are becoming more widespread. The global financial crisis that began in 2008 has altered the global economic environment and increased global economic insecurity (Zhang et al., 2020). After that, the globe witnessed the European sovereign debt crisis, the Ukraine-Russia conflict, unrest in the Middle East, and now the coronavirus epidemic (Ji et al., 2020). These events have significant ramifications for energy, precious metals, agriculture, and industrial markets, prompting many empirical investigations. The impact of macroeconomic uncertainty on commodity prices and volatility was investigated by Joëts et al. (2017) and indicated that while the safe-haven role of precious metals has been confirmed, agricultural and industrial markets are susceptible to variability and the level of macroeconomic uncertainty, respectively.

Gold, silver, platinum, and palladium are considered to be powerful worldwide precious metals, among which gold has an extremely dominant position (Baruník et al., 2016). Gold is a top-tier commodity for protecting against financial turmoil and dangers related to economic and market policies, as stated by O'Connor et al. (2015)

and Raza et al. (2018). Similarly, due to the low threshold involved in investing, silver is also employed in the same way as other alternative investments, and it has developed into an extra component that contributes to financial stability (Vigne et al., 2017). In addition to this, palladium and platinum were also able to capture the interest of the investors (Jain and Ghosh, 2013). These metals are regarded as stable investments on a global scale as a result of their better yields and diversity (Sikiru and Salisu, 2021). The increasing demand for these metals on the investment market can be attributed to the price fluctuations and volatility that have been witnessed. Because of this, the consistency of the prices of such commodities became an important factor in economic expansion (Wu et al., 2019; Ge and Tang, 2020). As a result, it is essential to fulfil the need of conducting in-depth research into the price fluctuations of these metals to get an understanding of the factors that contribute to price changes (Raza et al., 2023).

Another reason to conduct this research is that literature suggest numerous countries are continuously revising and releasing updated versions of their economic policies to maintain economic stability and foster the growth of economic activity. These frequent adjustments contribute to a rise in both the volatility and unpredictability of economic policy (Baker et al., 2016) . As adjustments are made, the contribution of economic policy becomes increasingly important in the growth of the financial sector. These accompanying risk shocks influence the macroeconomic level, manifesting themselves as decreased output, investments, and employment rate, as well as increased volatility in financial markets (Baker et al., 2016; Henzel and Rengel, 2017). As a result of this, significant economic developments can cause significant volatility in the financial markets, which can be seen as an indication of possible instability and has consequences for economic policies and investors risk diversification strategies.

When it comes to macroeconomic variables, inflation is one of the most significant factors since it indicates the rise in the prices of various commodities, which ultimately reduces the purchasing power of the average person Wulandari et al. (2019). McCown and Zimmerman (2007) found that inflation is becoming increasingly important in driving silver prices in a multi-factor Arbitrage Pricing Theory (APT). Silver's price was discovered to have a strong link with inflation expectations, making it an excellent indicator of the latter. However, gold appears to perform better in this function than silver.

Choudhry (2001) investigated the effect of inflation on stock returns, focusing on four countries in central Latin America that were experiencing high inflation rates, namely Chile, Mexico, Argentina, and Venezuela, and found that the effect of inflation on stock returns was significant. The relationship between stock return and inflation was tested using linear regression. The results revealed a significant influence on stock returns that were imposed by lags in the levels of inflation, rather than necessarily by leads in the levels of inflation. Additionally, the results indicated a negative association between inflation and stock returns during periods of hyperinflation.

Zhang and Wei (2010) suggested that gold beats other commodities in terms of giving rewards to investors and conferring social status and preserving the asset's value. Iqbal (2017) found that the demand for gold as a physical asset is increasing; investors have realized the significance of gold as a hedging asset against inflation in developed economies such as the United States of America (USA). However, in the emerging economies, especially in the Indian subcontinent, holding gold is considered prestige and is a storage of value and insurance against political instability. Therefore, emerging markets such as China and India were not surprising to be among the top ten countries in the world in terms of gold demand in 2015 (Tung, 2019).

Furthermore, Batten et al. (2010) investigated the relationship between monthly price changes in precious metals and macroeconomic factors such as business cycles, the monetary environment, and financial market sentiment. Their findings revealed that macroeconomic factors influence fluctuations in the price of precious metals.

However, the literature indicates that the exchange rate of the US dollar, as well as interest rates (Akram, 2009; Gruber and Vigfusson, 2018), economic activity (Klotz et al., 2014), and other macroeconomic factors (Śmiech et al., 2015; Zhang et al., 2020) are also significant sources of commodity price volatility. Cai et al. (2001) studied the effects of 23 macroeconomic announcements on the gold market, and they found that employment reports, Gross Domestic Product (GDP), Consumer Price Index (CPI), and personal income all have an impact on the market's performance. According to Arango et al. (2012) and Frankel et al. (2009), the loose monetary policy and the weakening of the dollar have contributed to commodity prices.

Mo et al. (2018) used the GARCH-MIDAS model to examine the macroeconomic causes of commodities futures (including agricultural commodity futures, metal futures, and oil futures) volatility in two emerging economies - China and India. The empirical findings for the Chinese market suggest that the uncertainties of both domestic and foreign macroeconomic variables are key drivers of the volatility of commodity futures, oil futures, and metal futures, except for aluminum. Furthermore, the results of the volatility pattern are more consistent, demonstrating that the uncertainty of macroeconomic variables has a statistically significant positive impact on the volatility of commodity futures, metal futures, and oil futures in the vast majority of cases. This implies that changes in macroeconomic variables will increase commodity futures volatility. The results from the Indian market indicate that both domestic and international volatility of macroeconomic variables has a more considerable economic impact on the volatility of commodity futures.

Adrangi et al. (2003) examined the correlation between silver and inflation in the United States. They used the American Industrial Production (IP) and the Consumer Price Index (CPI) as independent variables. Their findings indicate that an increase in inflation will decline economic activity and money demand. The authors further suggested that while this would reduce industrial demand for silver, it would likely raise investment demand due to silver's alleged capacity to operate as a hedge against inflation. Radetzki (1989) investigated the medium-and long-term factors affecting the price of silver and platinum. The study is carried out by distinguishing between the driving factors of supply and the driving forces of demand from 1972 to 1987. The findings revealed that silver mine production is considered more important than gold, which has a considerable stock relative to other commodities. On the demand side, the photographic, electrical, and jewellery industries dominate silver demand. Moreover, platinum prices are also influenced by industrial demand, primarily from the automobile industry. These findings lead Radetzki (1989) to infer that industrial demand and private inventories control the price of silver. However, the supply of platinum scrap was not found to be a driver.

Frankel and Hardouvelis (1983) reported that the overall price level does not provide a sensitive indicator of whether monetary policy is tight or loose, as the majority of prices are sticky. Interest rates are free to fluctuate, but they are a confusing indication of monetary policy because it is unclear whether changes in the interest rates are related to changes in the predicted inflation rate or changes in the real interest rate. As a result, they suggested that commodity prices are the optimal sensitive indicator. Furthermore, they found that individual commodity coefficients are frequently not statistically significant or are only marginally significant, whereas commodity combination coefficients are highly statistically significant.

Thorbecke and Zhang (2009) examined the impact of unexpected monetary policy changes on gold and silver. They considered the period from 1974–1979 and 1989–2006. However, 1980–1989 were removed due to the Fed's abandonment of fund rate targeting in 1979. Moreover, they began by employing the Romer and Romer (2000) hypothesis that increasing the federal funds rate could increase inflation by releasing the Federal Reserve's secret information regarding inflation. Following the second theory, developed by Gürkaynak et al. (2005), increasing the federal funds rate will reduce long-term projected inflation.

4.3 Methodology & Data

The methodological approach used for this study is quantitative, a well-established tradition for testing the combined effect of macroeconomic variables on the price efficiency of precious metals. The data used for this study is extracted from multiple sources, as shown in Table 3.1. The time-series data has its advantages and challenges to render it suitable for usage. It is essential to use the appropriate methodological approach and ensure data is compliant for the model to be employed.

The appropriate technique for the data being analysed in time series analysis is crucial since faulty model specification or use of the incorrect model leads to incomplete and inaccurate estimations. To ensure the integrity of the data, the unit root test is conducted prior to performing panel data regression to determine the stationary of the data. The data used for this study is cross country, hence falls under the category of the panel data. Therefore, the panel unit root test is the first step that is used to determine whether or not the relevant variables have stationary qualities. This is done so that false regression may be avoided. There are many different panel unit root tests that can be found in the research literature. Some examples of these tests include Breitung (2000), Choi (2001), Levin et al. (2002), and Im et al. (2003), to name a few. In this study, we use four different types of panel unit root tests that are used to investigate the stationary properties of these variables. The four tests used are: the Levin et al. (2002, LLC) test, the Im–Pesaran–Shin test (2003, IPS) test, and the Fisher-type ADF and PP tests (Choi,2001; Maddala and Wu 1999). The LLC (2002) test is derived from the ADF test and makes the assumption of homogeneity in the dynamics of the autoregressive coefficients for all panel units while maintaining independence on a cross-sectional level (Sehrawat & Giri, 2017). We make use of the IPS (2003) test, which makes it possible to have heterogeneous autoregressive coefficients. It suggests averaging the augmented Dickey–Fuller (ADF) unit root tests while allowing for varying orders of serial correlation.

The panel data unit root tests findings are reported in the Tables 4.2 and 4.3 of this study to check for stationarity. The data set covers 1979–2020, 41 years of data for five developed and emerging economies: the United States of America, the United Kingdom, Japan, China, and India. Using the adjusted data for stationarity, this empirical research analyses the combined effect of macroeconomic factors on the precious metal prices in developed and emerging economies. The study employs a dynamic-panel estimation approach to capture the combined effect of six macroeconomic variables - CPI, IP, SP, SIR, LIR, and UR- on the prices of three precious metals - gold, silver, and platinum across developed and emerging markets.

To account for the country specific effect, we have developed the dummy variable (i.e., COUNTRY). The data for palladium for all countries is not available; therefore, in this chapter, we have used three precious metals – gold (1305 Obs), silver (1061 Obs), and platinum (837 Obs) as their data has all the required observations. Although observations for three precious metals differ, this does not raise any methodological challenges for testing the combined effect of macroeconomic factors on precious metals prices. However, the palladium pricing data is available for each country, but an equal number of observations data is not available for each independent variable. Therefore, we have carried out a test for each country to address this limitation, which is reported in Chapter 3.

To test endogeneity and correlation between the variables, in this chapter, we employed panel least squares, fixed effects models, random-effects models, and the extended technique generalized method of moments (GMM). The GMM is considered a robust estimator that does not rely on assumptions about the distribution of the data generated during the data-producing process to operate. Both models have shown consistency in their respective findings. This proves the robustness of the data that provides high-level confidence when inferring conclusions from the model findings.

To evaluate the data and carry out the test, we used the Stata and the R software to complete all econometric exercises. These software's have been considered technically robust to provide results with a high level of confidence as they are extensively used in recent publications (Hashim, 2022; Maghyereh and Abdoh, 2022; Haque et al., 2015).

4.3.1 Descriptive Statistics

The descriptive statistics provide you with a critical sense of the dataset to be employed for analysis using regression analysis. The log prices of gold, silver, and platinum have been used to represent the activity of developed and emerging markets. The various macroeconomic variables examined with precious metals (gold, silver, and platinum) prices include consumer price index, industrial development, short- term and long-term interest rates, share prices, and an unemployment rate

The descriptive statistics of the data are presented in Table 4.1, including information on the mean, standard deviation, minimum and maximum prices, skewness, kurtosis, observations of three precious metals prices, and information on major eco- nomic variables. Table 4.1 shows that the mean values of three precious metals prices and the major macroeconomic variables differ slightly across developed and emerging economies.

The mean for gold, silver, and platinum prices are 7.53, 3.29, and 6.49, respectively, while the standard deviation was 2.28, 2.97, and 0.60, meaning that there was a small dispersion around the mean. These results are higher than the previous study (Batten et al., 2010a), which found a mean value of 0.00 and standard deviation of 0.04, 0.06, and 0.05 for all three precious metals in the United States between January 1986 and May 2006, a period of 245 monthly observations. The rationale for this study's higher mean finding is that it uses a broad data set spanning 1979–to 2020 and includes a cross-country analysis of five developed and emerging economies. Similarly, the mean values of independent variables (CPI. IP, SP, SIR, LIR, and UR) for gold, silver, and platinum are approximately the same.

We found a low standard deviation across developed and emerging economies in all three precious metals and major economic indicators, indicating that the data is clustered closely around the mean. This demonstrates that the price volatility of three precious metals and macroeconomic indicators is lower and more consistent across developed and emerging economies. However, gold, silver, and platinum short-term interest rates and the price of gold and silver are extremely volatile.

It is evident from Table that all variables, except for the price of gold, silver, and unemployment rate, are negatively skewed. Kurtosis values reveal that all variables follow the leptokurtic distribution, indicating that the distribution is too peaked, or the dataset has heavier tails than a normal distribution.

Table 4.1: Descriptive Statistics for Precious Metals Prices and Macroeconomic Factors

Variable	Mean	Median	SD	Minimum	Maximum	Skewness	Kurtosis	Observations
Gold	7.53	6.64	2.28	5.06	11.93	0.87	2.17	1305
CPI	4.47	4.59	0.32	3.44	5.15	-0.76	3.30	1305
IP	4.32	4.59	0.69	1.67	4.82	-2.65	9.07	1305
SP	4.02	4.24	0.73	1.70	4.94	-1.46	4.46	1305
SIR	0.99	1.43	1.18	-2.21	2.93	-0.63	2.46	1305
LIR	1.35	1.55	0.87	-1.56	2.79	-0.52	2.17	1305
UR	1.70	1.69	0.33	0.83	2.69	0.03	2.57	1305
Silver	3.29	2.10	2.97	0.62	11.03	1.58	3.94	1061
CPI	4.47	4.50	0.31	3.77	5.15	-0.31	2.48	1061
IP	4.29	4.59	0.75	1.67	4.78	-2.50	7.88	1061
SP	4.03	4.23	0.68	1.83	4.94	-1.25	3.85	1061
SIR	1.13	1.60	1.17	-2.21	2.73	-1.08	3.14	1061
LIR	1.57	1.61	0.68	-1.29	2.77	-0.91	3.54	1061
UR	1.75	1.72	0.32	0.99	2.69	0.01	2.51	1061
Platinum	6.49	6.42	0.60	5.21	7.68	-0.01	1.90	837
CPI	4.50	4.54	0.22	3.88	4.81	-0.74	2.89	837
IP	4.26	4.59	0.82	1.67	4.69	-2.28	6.43	837
SP	4.22	4.31	0.41	3.06	4.87	-0.83	2.95	837
SIR	0.89	1.42	1.23	-2.21	2.73	-0.79	2.54	837
LIR	1.38	1.53	0.68	-1.56	2.54	-0.98	4.23	837
UR	1.73	1.69	0.34	0.99	2.69	0.12	2.26	837

Note: The statistics reported in Table 4.1 are based on the monthly data.

4.3.2 Panel Data Regression

Firstly, we employed the panel data regression econometric technique to examine the combined effect of macroeconomic variables - Consumer Price Index (CPI), Industrial Production (IP), Share Price (SP), Short-term Interest Rate (SIR), Long-term Interest Rate (LIR), and Unemployment Rate (UR) on the prices of precious metals - gold, silver, and platinum across developed and emerging markets. Panel data regression is appropriate for this type of study since it accounts for variable heterogeneity across precious metals and countries over time. Moreover, it incorporates both time series and cross-section observations and gives a more informative analysis with reduced collinearity across distinct variables, resulting in more efficient results (Ahuja and Kalra, 2020).

Lu et al. (2022) and Aslam et al. (2022) identified several advantages of using panel data, such as it provides more useful data, greater variability, less collinearity among the variables, and more degrees of freedom, resulting in greater efficiency. Panel data models outperform other methods for capturing the heterogeneity of cross-sectional units and time dimensions. They are better suited to studying the dynamics of change and complex behavioural models than other methods to reduce estimation bias and multicollinearity (Baltagi et al., 2005; Gujarati et al., 2012). In the context of time series analysis, panel data has several advantages, which have been addressed by (Frees et al., 2004). It does not necessitate the use of extremely large time series. Several methods used in classical time series analysis require a series of at least 30 observations, which can be a disadvantage for two reasons. The first is that data for so many consecutive periods may not be available. The second is that it may be unreasonable to use the same model for data over a long period. Moreover, the model can be derived more easily from panel data when observations are made on the series for all individuals in the sample (Sheytanova, 2015).

Figure 4.1: Econometric Techniques

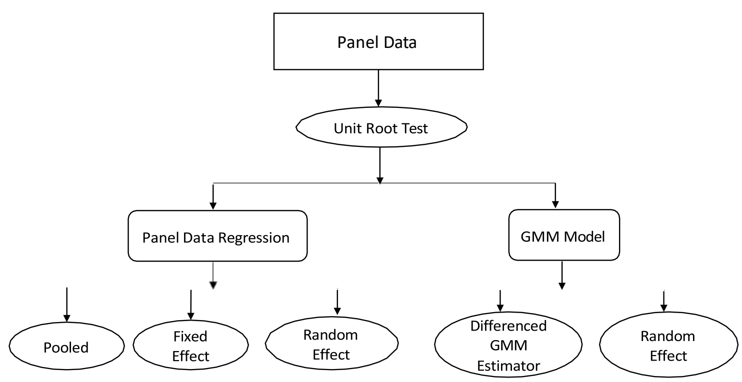


Figure : Developed by Author

Panel data estimation models are often classified into three types: the constant coefficient (pooled), the fixed effects (FE), and the random effects (RE) regression models (Ahuja and Kalra, 2020) as shown in Figure . To begin, the Pooled Least Squares (OLS) model, which is basically focused on minimising the sum of squared residuals, is predicated on the assumption that the intercept and coefficient are constant throughout time and cross section, while statistical noise captures time and cross-sectional variations (Panda and Trivedi, 2015). As a result of this, the Fixed

Effects model (FEM), also known as the "Least-Squares Dummy Variable (LSDV) model," estimates the intercept as the coefficient of dummy variables. This model permits the intercept to vary for each cross-section, allowing for the individual effect to be taken into account. In addition, the Random Effects model (REM), rather of treating the intercepts as fixed constants, treats them as random variables. The intercepts are expected to be independent of the error term as well as mutually independent of one another in their relationships (Selimi et al., 2017).

Baltagi et al. (2005) and Brooks (2014b) also suggested that the FE model provides different intercept terms for each subject, which are constant over time; however, the RE model assumes that the intercepts for each cross-section are generated randomly from a vast population. Unmodeled unit heterogeneity in time-series cross-section data complicates the general study of time-series cross-section data. These problems include erroneous estimates of effect sizes and unnecessarily deflated confidence levels. These issues can be mitigated by using random or fixed-effects models; however, whether it is appropriate to use random or fixed-effects models depends on factors unknown to the researcher (Esarey and Jaffe, 2017). A random-effects model is inappropriate when a fixed-effect model is appropriate; a fixed-effects model is inappropriate when a random-effects model is appropriate because it limits power and makes it impossible to analyse effects that only vary between (and not within) units (Wooldridge, 2010).

4.3.3 Hausman Test

To determine the suitability of a model, the Hausman test is employed in this study to decide whether to adopt a Fixed Effect Model (FEM) or a Random Effect Model (REM). Standard textbooks also recommend using the Hausman (1978) test for panel data analysis to select a fixed or random-effects model (Wooldridge, 2010; Cameron and Trivedi, 2005). As a result, we used the Hausman test (1978) to determine which model, Fixed Effect or Random Effect, is more suited for the data set used for this study (Esarey and Jaffe, 2017). The null hypothesis for this test is that the FEM and REM estimators are not significantly different. Specifically, if ε_{it} and the X's (explanatory variables) are assumed to be uncorrelated, REM may be appropriate; however, if ε_{it} and the X's are expected to be correlated, FEM may be appropriate (Gujarati, 2003). The rule of thumb is that if the probability of the Chi-square value is less than 0.05, we should prefer the fixed effects estimates; otherwise, the random effect estimates should be used (Singh and Sharma, 2016).

Explicitly, let $\alpha_i = \beta_o + \beta_2 Z_i$, then equation 24 becomes

$$Y_{it} = \beta_1 X_{it} + \alpha_i + \varepsilon_{it} \qquad \text{Equation 24}$$

Equation 12 denotes the fixed effects regression model used to calculate the fixed effects on real output, where $\alpha_i (i = 1 \ldots n)$ is the country's unknown intercept. However, the random effects model is denoted by the following equation 25:

$$Y_{it} = X_{it}\beta + \alpha_i + \mu_{it} + \varepsilon_{it} \qquad \text{Equation 25}$$

where μ_{it} is the between-entity (country) error; ε_{it} is the country error that occurs within-entity (country). Laichena and Obwogi (2015) similarly employed panel data regression and the Hausman test to examine the impacts of macroeconomic variables - Stock Market, Interest rate, Exchange rate, Inflation Rate on stock returns in East Africa. They found a strong association between macroeconomic variables and stock returns in East Africa. Additionally, the study proposed that officials in East Africa work to improve the region's macroeconomic environment to boost stock returns.

Followings are three empirical models used in this study to estimate the combined effect of macroeconomic variables on precious metals prices.

$$Gold_{it} = \beta o + \beta_1 CPI_{it} + IP_{it} + SP_{it} + SIR_{it} + LIR_{it} + UR_{it} + \mu_{it} \qquad \text{Equation 26}$$

$$Silver_{it} = \beta_0 + \beta_1 CPI_{it} + IP_{it} + SP_{it} + SIR_{it} + LIR_{it} + UR_{it} + \mu_{it} \qquad \text{Equation 27}$$

$$Platinum_{it} = \beta_0 + \beta_1 CPI_{it} + IP_{it} + SP_{it} + SIR_{it} + LIR_{it} + UR_{it} + \mu_{it} \qquad \text{Equation 28}$$

where i denotes country and t denotes time. Gold, Silver and platinum are the dependent variables which capture the log prices of respective countries. μ_{it} is the error term.

4.3.4 Generalized Method of Moments (GMM) Model

The rationale of choosing the GMM model for our estimation is because it accounts for the endogeneity of the lagged dependent variable in a dynamic panel model- where the explanatory variable and the error term in the model are correlated; omitted variables bias; unobserved panel heterogeneity; and measurement errors.

One of the most fundamental goals in econometrics and statistics is to discover techniques that allow the researcher to estimate the unknown parameters of a specific model for a given data set. The minimization or maximisation of a criterion function is used as a basis for estimate procedures (M-estimators). The most significant distinction between these estimators is the amount of information that must be provided about the model. The maximum likelihood estimation technique, which is the most extensively used of these techniques, necessitates the entire specification of the model and its probability distribution. The Generalized Method of Moments (GMM) Model does not necessitate this level of comprehensive knowledge. It merely requires the declaration of a set of moment requirements that the model must satisfy to be valid (Mátyás et al., 1999).

A standard method for removing permanent unobserved heterogeneity from an equation is to first difference the equation, and then to use lagged levels of the series as instruments for the predetermined and endogenous variables in first differences (Anderson and Hsiao, 1981; Holtz-Eakin et al., 1988a; Arellano and Bond, 1991). The GMM empirical framework is offered in two forms: 1) the differenced-GMM estimator from Arellano and Bond (1991) and 2) the system-GMM estimator from Blundell and Bond (1998, 2000). The coefficients of the differenced GMM estimator are derived from moment constraints on the covariances between the regressors and the error term. Moreover, the differenced GMM adjusts for endogeneity, but the estimate suffers from a substantial downward finite sample bias, especially when the number of time series data is small (Dayanandan and Donker, 2011). In response to these findings, Ahn and Schmidt (1995) investigated the nonlinear moment conditions implied by the conventional error components formulation and demonstrated that asymptotic variance ratios could significantly improve.

Blundell and Bond (1998) examined alternate estimators that impose additional constraints on the initial conditions process to enhance the typical first-differenced instrumental variables estimator's features. Dayanandan and Donker (2011) and Blundell et al. (2001) examined the use of both the differenced GMM estimator and the system GMM estimator approaches. They suggested that using the system GMM estimator significantly increases the precision and significantly decreases the finite sample bias. Furthermore, they asserted that the system GMM estimator produces good predictors for the endogenous variables in the model, even when the series is quite persistent in nature. As a result, we use the panel system GMM estimator as our primary estimating approach. To establish a baseline GMM equation, we used the equation 29 is as follows:

$$y_{it} = \propto y_{i,t-1} + X_{it}\beta + \varepsilon_{it} \qquad \textit{Equation 29}$$

$$\varepsilon_{it} = \mu_i + \nu_{it}$$

$$E[\mu_i] = E[\nu_{it}] = E[\mu_i \mu_{it}] = 0$$

where i denotes country and t denotes time. y is the dependent variables (Gold, Silver and Platinum Prices) and X is a vector of explanatory variables including lagged values of independent variables (CPI, IP, SP, SIR, LIR and UR). The disturbance term has two orthogonal components: the fixed effects, μ_i and random shocks, υ_{it}. Subtracting $y_{i,t-1}$ from both sides of 29, we get the equation 30 which is estimated.

$$\Delta y_{it} = (\propto -1)y_{i,t-1} + X_{it}\beta + \varepsilon_{it} \qquad \textit{Equation 30}$$

The distinction GMM estimation begins with data differentiation to reduce fixed effects. The system GMM complements the difference GMM by estimating both differences and levels simultaneously, with the two equations being instrumented differently.

The rational for choosing the combined impact over the cross-country for macroeconomic variables on precious metals prices across specific developed and emerging economies is because of contemplating the addressing of the country-specific effect using dummy variables, such as (COUNTRY). Moreover, there is the possibility of an endogeneity problem and concerns with reverse causality when looking at the impact of macroeconomic variables on the price of precious metals. Hence, to overcome these issues, we utilized the System GMM since it addresses both the endogeneity as well as the reverse causality issues, thereby overcoming biases typically associated with pooled ordinary least squares (OLS) estimation or standard GMM estimation, both of which suffer from small-sample biases and do not account for individual country-specific fixed effects (Baltagi 2013). Even though it is difficult to establish the appropriate instruments for all of the variables that are involved in the relationship between macroeconomic variables and the price of precious metals, this problem may be efficiently addressed by using SYS-GMM estimate (Li et al., 2017).

4.4 Empirical Findings

The current study investigates the combined effect of macroeconomic factors on precious metals pricing in developed and emerging economies from 1979–to 2020 using the panel data model stated in equations (24, 25, 26, 27 and 28). Prior to running the regressions, it is necessary to conduct a stationarity test on all of the independent variables in the model. Several statistical tests have been developed in order to determine whether or not the series is stationary. The Augmented Dickey-Fuller tests (Dickey and Fuller, 1979, 1981) are the most commonly used methods for testing procedures. We employ two-unit root tests, Dickey and Fuller (1979) and Phillips and Perron (1988), as the data must be stationary to perform regression analysis. The following ADF test model allows for comparing the null hypothesis that a series has a unit root ($a = 0$) against an alternative that the series is stationary ($a < 0$).

$$\Delta xt = \alpha x_{t-1} + \sum_{i=1}^{k} \beta \, \Delta x_{t-1} + \varepsilon_t \qquad \textit{Equation 31}$$

In equation 31, where Δ denotes the first difference, xt denotes the series to be tested, t represents the time trend, and k means the optimal number of lags as determined by some model selection criteria. Phillips and Perron (1988) and Perron (1990) developed a non-parametric testing procedure similar to the ADF test but with the ability to correct for auto-correlated residuals. We use the null hypothesis to test the data for the unit root to ensure that data does not exhibit non-stationary behaviour. Moreover, the data has been tested for stationarity in both tests at both log levels and their first differences. The results of all panel data unit root tests are presented and described in subsection 4.4.1.

4.4.1 Panel Data Unit Root Test Results

We apply four distinct unit root tests to determine the order of integration for all dependent and independent variables to evaluate the unit root features of variables as shown in Tables 4.3 and 4.4. The probability values are used as a "rule of thumb" to establish if the probability value of test statistics is less than 5% confidence level, then the Null Hypothesis (i.e., Ho: Panel Data has a Unit Root in the Data Series) is rejected and the Panel Data is stationary. However, if the probability value of test statistics is greater than 5% confidence level then we can accept the Null Hypothesis and the Panel Data is non-stationarity, and we have to take the first difference. The results of both the unit root tests are presented in Table 4.2 and 4.3.

The unit root exists in all dependent and a few independent variables, as shown in Tables 4.3 and 4.4. As a result, we cannot reject the null hypothesis and conclude that all precious metal prices (gold, silver, and platinum) and a few variables (SP, SIR, LIR and UR) are non-stationary at the level. Thus, we converted non-stationary variables to their first differences before running the regression model, and all became stationary at the first difference. On the other hand, the results of Table 4.4 indicate that CPI and IP are stationary at the level, and we reject the null hypothesis, and data is stationary.

Table 4.2: Panel Data Unit Root Test – Precious Metals Prices

		Level		1st diff	
	Method	**Statistics**	**Prob**	**Statistics**	**Prob**
Gold	Levin, Lin & Chu t*	0.84393	0.8006	-18.6984	0.0000**
	Im, Pesaran and Shin W-stat	1.03356	0.8493	-20.4676	0.0000**
	ADF - Fisher Chi-square	6.72751	0.7509	339.502	0.0000**
	PP - Fisher Chi-square	9.65029	0.4717	533.776	0.0000**
Silver	Levin, Lin & Chu t*	0.85369	0.8034	-15.5328	0.0000**
	Im, Pesaran and Shin W-stat	-0.08497	0.4661	-18.0181	0.0000**
	ADF - Fisher Chi-square	11.0757	0.1974	273.575	0.0000**
	PP - Fisher Chi-square	11.5954	0.1702	410.927	0.0000**
Platinum	Levin, Lin & Chu t*	-0.82997	0.2033	-16.049	0.0000**
	Im, Pesaran and Shin W-stat	0.47142	0.6813	-14.9698	0.0000**
	ADF - Fisher Chi-square	3.11338	0.7945	191.581	0.0000**
	PP - Fisher Chi-square	3.06789	0.8003	380.836	0.0000**

Note: (*) = Data is stationarity at level data; (**) = Data is stationarity at first difference.
Statistic Values are calculated at 5% Level of Significance

Table 4.3: Panel Data Unit Root Test – Macroeconomic Variables

		Level		1st diff	
	Method	Statistics	Prob	Statistics	Prob
CPI	Levin, Lin & Chu t*	-9.80302	0.0000*	-	-
	Im, Pesaran and Shin W-stat	-4.07965	0.0000*	-	-
	ADF - Fisher Chi-square	54.0303	0.0000*	-	-
	PP - Fisher Chi-square	77.7916	0.0000*	-	-
IP	Levin, Lin & Chu t*	-1.58763	0.0562*	-	-
	Im, Pesaran and Shin W-stat	-2.12196	0.0169*	-	-
	ADF - Fisher Chi-square	35.2836	0.0001*	-	-
	PP - Fisher Chi-square	100.592	0.0000*	-	-
SP	Levin, Lin & Chu t*	-2.01491	0.022	-13.4048	0.0000**
	Im, Pesaran and Shin W-stat	-0.27267	0.3926	-17.4351	0.0000**
	ADF - Fisher Chi-square	8.28355	0.6012	285.528	0.0000**
	PP - Fisher Chi-square	9.58636	0.4775	454.535	0.0000**
SIR	Levin, Lin & Chu t*	0.30685	0.6205	-13.6091	0.0000**
	Im, Pesaran and Shin W-stat	0.15822	0.5629	-14.6654	0.0000**
	ADF - Fisher Chi-square	9.57733	0.4783	218.735	0.0000**
	PP - Fisher Chi-square	9.24763	0.5088	401.658	0.0000**
LIR	Levin, Lin & Chu t*	3.27402	0.9995	-19.5857	0.0000**
	Im, Pesaran and Shin W-stat	1.74817	0.9598	-18.0325	0.0000**
	ADF - Fisher Chi-square	8.39307	0.5905	306.603	0.0000**
	PP - Fisher Chi-square	6.40457	0.7802	404.100	0.0000**
UR	Levin, Lin & Chu t*	0.67121	0.749	-12.1914	0.0000**
	Im, Pesaran and Shin W-stat	1.20888	0.8866	-17.7217	0.0000**
	ADF - Fisher Chi-square	9.78595	0.4595	283.068	0.0000**
	PP - Fisher Chi-square	9.11342	0.5214	482.677	0.0000**

Note: (*) = Data is stationarity at level data; (**) = Data is stationarity at first difference.
Statistic Values are calculated at 5% Level of Significance

4.4.2 Correlation Analysis

Correlation coefficients between dependent and independent variables are provided in the correlation matrix Tables 4.4, 4.5 and 4.6. Correlation analysis is used to explore the sensitivity of data outliers and multicollinearity. Multicollinearity is a fundamental component in the application of Multivariate Regression Models. When the predictor variables in a regression model are significantly correlated, this is referred to as multicollinearity (Ali, 2011).

We estimate Pearson's correlation coefficients to determine the strength of the linear link between the regression variables. The Pearson correlation matrix, variance inflation factor (VIF), and tolerance values (1/VIF) of all explanatory variables are shown in Tables 4.4, 4.5 and 4.6 to determine multicollinearity. As a general rule, correlation coefficients should not exceed 0.80. None of the correlations between independent variables exceed 0.8, indicating no multicollinearity (Gujarati and Porter, 2009). The VIF value, on the other hand, should be less than 10, or the tolerance value should be larger than 10. The findings imply that multicollinearity is not a significant issue, as evidenced by the vast majority of correlation coefficients being less than 0.8 (Cooper et al., 2006). Moreover, the greatest VIF value is 6.41, which is significantly lower than 10, and the tolerance values are more than 0.10 (Khan, 2021).

Table 4.4 also demonstrated a negative correlation between macroeconomic indicators (IP, SIR, LIR, and UR) and the gold price. However, as indicated Table 4.5 macroeconomic variables (IP, LIR, and UR) are inversely linked with the silver price. Finally, Table 4.6 results showed that the macroeconomic indicators (SIR and LIR) are adversely connected with platinum prices.

Table 4.4: Correlation Matrix - Gold

Variables	Gold	CPI	IP	SP	SIR	LIR	UR	VIF	1/VIF
Gold	1								
CPI	0.6043	1						6.14	0.162928
IP	-0.0956	0.0033	1					1.61	0.620767
SP	0.3834	0.8969	0.1735	1				6.41	0.155992
SIR	-0.3167	-0.5353	-0.2111	-0.5355	1			3.82	0.262017
LIR	-0.5619	-0.6062	-0.1836	-0.6347	0.7935	1		5.09	0.196331
UR	-0.5221	-0.4882	0.3259	-0.4565	0.143	0.4891	1	2.55	0.391833

Table 4.5: Correlation Matrix - Silver

Variables	Silver	CPI	IP	SP	SIR	LIR	UR	VIF	1/VIF
Silver	1								
CPI	0.6668	1						5.32	0.187991
IP	-0.5166	-0.1041	1					1.66	0.601872
SP	0.3358	0.8756	0.0783	1				6.09	0.164096
SIR	0.0564	-0.4682	-0.1565	-0.4819	1			3.7	0.270059
LIR	-0.0357	-0.6142	-0.0535	-0.6901	0.7771	1		4.89	0.204527
UR	-0.4168	-0.4929	0.4886	-0.4387	-0.0087	0.3664	1	2.54	0.393277

Table 4.6: Correlation Matrix - Platinum

Variables	Platinum	CPI	IP	SP	SIR	LIR	UR	VIF	1/VIF
Platinum	1								
CPI	0.3266	1						5.21	0.076616
IP	0.6058	-0.3422	1					2.93	0.340896
SP	0.4262	0.8385	-0.0204	1				5.6	0.178445
SIR	-0.6448	-0.6558	-0.1625	-0.5497	1			4.76	0.210259
LIR	-0.4667	-0.793	-0.0471	-0.7645	0.745	1		4.44	0.225121
UR	0.3091	-0.5268	0.5601	-0.4267	-0.099	0.28	1	2.85	0.350948

4.4.3 Regression Analysis

The estimates of econometric models, such as "pooled OLS," "Fixed Effects," and "Random Effects," as well as the findings of the GMM model, are presented in this section.

4.4.3.1 Pooled OLS Regression Model

We employ the pool regression model. The findings of the pooled OLS regression, as shown in Table 4.7 suggested that all macroeconomic determinants significantly impact the prices of precious metals. In the case of the individual unobservable heterogeneity linear regression method, accordingly, pooled OLS estimates reveal bias and cannot be considered consistent. Hence, the results of this methodology should be interpreted with caution (Hiestand et al., 2005). Since the considered model precludes heterogeneity and individuality in data, we run the fixed and random effect technique, allowing for heterogeneity and individuality in precious metals prices. As a result, we have estimated the FEM and REM models, and we have found that the FEM model is preferable to the REM model using the Hausman test. We also applied the GMM model to strengthen the robustness of our findings even further.

Table 4.7: Pooled Regression Results

	Model 1	**Model -2**	**Model-3**
	Gold	**Silver**	**Platinum**
CPI	9.51**	14.27**	2.38**
	(0.27)	(0.22)	(0.16)
IP	0.30**	-1.32**	0.57**
	(0.06)	(0.05)	(0.02)
SP	-3.5**	-2.78**	-0.16**
	(0.12)	(0.10)	(0.06)
SIR	0.73**	0.69**	-0.08**
	(0.06)	(0.05)	(0.01)
LIR	-1.78**	0.66**	0.23**
	(0.09)	(0.09)	(0.03)
UR	-0.92**	1.33**	0.36**
	(0.17)	(0.15)	(0.05)
R^2	0.70	0.90	0.77
No of Obs	1305	1061	837
COUNTRY	Yes	Yes	Yes

Note: ** denote statistical significance at the 5%, level. (p-value <0.05) and the values in ( ) indicate standard error

4.4.3.2 Fixed Effect and Random Effect Estimates

We ran fixed and random effect regressions and used the Hausman test to determine the most appropriate specification. As a result, we concluded that the fixed effects model is the preferred estimate for these data as the probability of the Chi-square value is less than 0.05 (Singh and Sharma, 2016). The results of Table are discussed in detail in this section.

Table results indicate that the Consumer Price Index (CPI) positively affects the gold and silver prices. These findings demonstrate that gold and silver price returns can predict using the CPI. Our findings corroborate Toraman et al. (2011) and Sharma (2016). Adrangi et al. (2003a) found that investors can use gold and silver as a short- and long-term inflation hedge, depending on their investment horizons. Similarly, Simpson et al. (2007) found that an increase in the CPI increases the gold and silver prices when all other variables are constant. Additionally, the findings suggested that the CPI had the most significant effect on the price of silver.

Table 4.8: Fixed Effect Estimates

	Model 1 Gold	Model 2 Silver	Model 3 Platinum
CPI	15.78** (0.45)	13.83** (0.85)	1.53** (0.26)
IP	0.72** (0.06)	-0.66** (0.06)	0.57** (0.01)
SP	-0.33** (0.22)	-0.95** (0.20)	-2.83** (0.03)
SIR	0.35** (0.07)	0.44** (0.06)	0.22** (0.01)
LIR	-1.60** (0.10)	1.67** (0.18)	0.21** (0.02)
UR	-5.00** (0.29)	-1.55** (0.26)	0.46** (0.03)
R^2	0.79	0.93	0.99
No of Obs	1305	1061	837
COUNTRY	Yes	Yes	Yes

Note: ** denote statistical significance at the 5%, level. (p-value <0.05) and the values in ( ) indicate standard error

For the UK and US, Bampinas and Panagiotidis (2015) also looked at gold and silver's long-run hedging capabilities against alternative measurements of the CPI. They reported that gold has a better potential to hedge inflation in the US than in the UK on average. Moreover, the UK has a time-varying long-run relationship with silver, but not US consumer prices. The Consumer Price Index (CPI), on the other hand, negatively effects the platinum price as shown in Table . Chevallier et al. (2014) reported similar findings in the Eurozone setting, implying that platinum exhibits a negative sensitivity to the EMUCPI. Mochnacz (2013) investigated the inflation-hedging capacity of four precious metals: gold, silver, platinum, and palladium in the United States across two sample periods (1974/2013 and 1990/2013). They concluded that commodity prices began to skyrocket, and inflation volatility worsened in 2005. However, from 2000 and 2005/2006, the association between platinum returns and inflation was negative and poor for holding periods of three to five years.

Industrial Production (IP) growth is the most extensively used indicator of economic activity and a closely watched economic indicator of the business cycle (Herrera et al., 2011; Ludvigson et al., 2021; Baumeister and Hamilton, 2019). Our findings show a positive and statistically significant association between Industrial Production (IP), gold, and platinum prices but a negative relationship between IP and silver prices. Adrangi et al. (2003) also suggested that industrial production is negatively correlated with gold/silver prices in the long run. Thus, an increase in the rate of industrial production indicates an increase in the consumption rate of industrial commodities, which in turn leads to an increase in the price of gold and platinum. These findings are consistent with (Pindyck and Rotemberg, 1988; Wen et al., 2021, 2022). In terms of industrial production, the study's findings confirmed the findings of Patel (2012), who stated that industrial production is a highly significant element and that policymakers should make every effort to stimulate the expansion of the sector through appropriate policy measures.

The present study also found a negative and statistically significant relationship between the share price (SP) and all three precious metal prices - gold, silver, and platinum. Similarly, Ziaei (2012) explored whether there was a relationship between the stock markets of Indonesia, Malaysia, the Philippines (including Singapore), Thailand (including Thailand), China, Japan, and South Korea (including South Korea) and the price of gold. The study's findings revealed a negative and statistically significant relationship between the stock exchange markets and the price of gold in these countries. Bailey and Bhaopichitr (2004) also investigated the relevance of silver in the stock market under various conditions; they found that this precious metal has the potential to decide the expected risk premium in the stock market or that it does not have this power. Furthermore, silver has a major impact on the stock market when forecasting changes in trade, economic growth, and inflation levels.

Table depicts that short-term interest rate (SIR) has a positive and significant effect on the prices of gold and silver. However, SIR indicates a positive but small effect on the platinum price. Furthermore, the long-term interest rate (LIR) has a negative impact on the price of gold and a positive impact on the price of silver and platinum. Baur (2011) found similar findings that the association between gold and long-term interest rates is distinct from the relationship between gold and short-term interest rates. Using monthly data spanning 30 years, he demonstrated that lower short-term interest rates positively affect gold prices, whereas higher long-term interest rates negatively impact. The findings of Fortune (1987a) also suggested a negative relationship between gold and long-term interest rates. Erb and Harvey (2013) observed a similar type of correlation between the real price of gold and the real interest rate in the United Kingdom and the United States. They reported a negative correlation of 0.82 over 15 years in the United States and about 0.31 over 30 years in the United Kingdom. They made a point of emphasising the pitfalls of "correlation as causality" but believe the relationship is compelling.

The empirical findings outcomes of this study also show that the unemployment rate has a negative and statistically significant impact on the prices of gold and silver but has a positive effect on the prices of platinum. One possible explanation for such a relationship could be that unemployment affects consumers' purchasing power, as they require finance for consumption. However, there is an observed abnormality in that the demand for platinum rises. This difference in precious metals prices could be attributed to their different uses. Platinum is used in the industrial process, which might be one such explanation for the rise in the price of platinum. This finding is supported by (Khoury, 2015) in that there is a high usage of platinum in the European automobile sector. Furthermore, Apergis et al. (2014) also reported the negative relationship between the unemployment rate and precious metals, thus highlighting the inverse relationship between the macroeconomic environment and its impact on precious metals' demand and prices.

Hashim et al. (2017) studied the impact of the macroeconomic factors on gold prices in the world's largest gold-consuming countries - India, China, the United States, Turkey, and Saudi Arabia. Hashim et al. reported a positive relationship between gold and macroeconomic factors. In a previous study by Christie-David et al. (2000a) also used intraday data collected over four years (1992-1995) to investigate the impact of macroeconomic news releases on gold and silver prices. They also found that the unemployment rate does affect both gold and silver price. These results corroborate the empirical findings of this study, and the analysis is consistent with the theory and logic of the integrated economic system, where consumers have competing desires but a limited income. Thus, they substitute ownership of precious metals with consumable goods.

Table 4.9: Random Effect Estimates

	Model 1	Model 2	Model 3
	Gold	**Silver**	**Platinum**
CPI	9.51**	14.27**	2.08**
	(0.27)	(0.22)	(0.61)
IP	0.30**	-1.32**	-3.74**
	(0.06)	(0.05)	(0.03)
SP	-3.50**	-2.78**	-0.37**
	(0.12)	(0.11)	(0.03)
SIR	0.73**	0.70**	-0.04**
	(0.06)	(0.05)	(0.01)
LIR	-1.78**	0.67**	0.09**
	(0.09)	(0.01)	(0.02)
UR	-0.92**	1.33**	0.22**
	(0.17)	(0.15)	(0.03)
R^2	0.68	0.91	0.97
No of Obs	1305	1061	837
COUNTRY	Yes	Yes	Yes

Note: ** denote statistical significance at the 5%, level. (p-value <0.05) and the values in ( ) indicate standard error.

4.4.4 Robust Test (System Generalized Method of Moments (GMM))

To conduct the robustness of the previous results, we employed the two-step system generalised method of moments (GMM) estimator. The literature suggested that a lagged explanatory variable may correlate with the error terms, leading to an endogeneity concern. In this instance, the standard panel estimator, such as pooled OLS, random or fixed effects, is significantly biased because it does not account for the serial autocorrelation of the error terms (Nickell, 1981). As a result, considering the dynamic qualities of this study, generalised methods of moments (GMM)-a multivariate dynamic panel estimator are employed. Arellano and Bond (1991) developed the difference GMM model to overcome the problem of endogeneity. This estimate approach uses the first difference of independent variables as instruments to deal with the correlation between error terms (individual unobserved heterogeneity) and the lagged dependent variable. However, the difference GMM is useless and has poor predictive performance in short panels (N>T), that is, where the number of observations is greater than the number of time dimensions (Blundell and Bond, 1998). The system GMM estimator concurrently incorporates both equations regarding levels and differences to overcome this constraint. System GMM is preferable to difference GMM as it allows for additional instruments that are more successful in dealing with autocorrelation and endogeneity issues. The two-stage least square (2SLS) system GMM estimator is preferred over the one-step system GMM estimator because it provides greater accuracy and efficiency (Baltagi, 2008). Hence, we employ the two-stage least square (2SLS) system GMM estimator for this study to ascertain that the prior findings (i.e., Fixed Effect) are consistent. Moreover, we use diagnostic tests such as Wald F, AR(1), AR(2), and Hansen **J** to determine whether or not the model is appropriate. The Wald F test's null hypothesis must be rejected for a viable model, but the AR(2) and Hansen **J** statistics do not require rejection.

Table summarises the panel estimation findings for the gold, silver, and platinum equations - 1, 2, and 3 using the System GMM approach for 1979 – 2020. All variables in the model are statistically significant for the system GMM version. Moreover, the two Step GMM results are similar to the fixed effect estimates. The empirical findings reported in Table 4.8 further demonstrate that macroeconomic factors positively impact on the prices of precious metals - gold, silver, and platinum across developed and emerging markets. The findings are consistent with theory in that the macroeconomic variables impact cross country and precious metals are interconnected with the global market's volatility. The results also suggest that precious metals price movements provide explanation of economic shocks that are reported and discussed in chapter 2, where weak form efficiencies are tested, and their economic significance explored. The findings of this study corroborate theory and practice as discussed by Zhang et al., (2020); and suggest macroeconomic factors have impact on precious metals thereby causing economic events. The results of chapter 4 are complimented by findings in chapter 3, where we have investigated the long-run and short-run relationship between prices of precious metals and macroeconomic factors using various econometric techniques. The findings of chapter 3 also proved that prices of precious metals fluctuate in response to changes in macroeconomic factors.

Table 4.10: System Generalized Method of Moments (GMM) Results

	Model 1	Model 2	Model 3
	Gold	**Silver**	**Platinum**
CPI	9.15**	2.65**	1.66**
	(0.57)	(0.78)	(0.23)
IP	0.74**	-1.18**	0.48**
	(0.14)	(0.12)	(0.03)
SP	-6.24**	-0.84**	-1.55**
	(0.54)	(0.35)	(0.96)
SIR	3.10**	0.94**	0.89**
	(0.26)	(0.25)	(0.03)
LIR	-5.18**	0.40**	0.19**
	(0.31)	(0.31)	(0.04)
UR	-0.05**	-2.90**	0.65**
	(0.39)	(0.28)	(0.05)
AR (1)	0.50	0.83	0.73
AR (2)	0.25	0.37	0.32

Note: ** denote statistical significance at the 5%, level. (p-value <0.05) and the values in ( ) indicate standard error.

4.5 Conclusion

This study set out to assess the combined effect of macroeconomic factors (Consumer Price Index (CPI), Industrial Production (IP), Share Price (SP), Long-term Interest Rate (LIR), Short-term Interest Rate (SIR), and Unemployment Rate (UR)) on the pricing of precious metals (Gold, Silver, and Platinum) for developed and emerging economies. By comparing the macroeconomic impacts of the United States of America, the United Kingdom, Japan, China, and India on precious metals prices, this study determines whether macroeconomic factors in these economies cause precious metals prices to rise or fall and quantifies the magnitude and significance of these effects.

To determine the relevance of and identify the critical factors impacting the pricing of the world's most valuable metals, we employed a panel data regression and a dynamic two-step GMM model. The study considered the monthly closing prices of precious metals and CPI, IP, SP, LIR, SIR, and UR, including 1305 monthly observations of gold, 1061 monthly observations of silver, and 837 monthly observations of platinum due to the absence of data for certain countries before too and during the sample period 1979 to September 2020.

This study contributes to the literature by demonstrating the significance of the precious metal markets and sheds light on the dynamic behaviour of the information transmission in the global metal market system. Overall, our analysis confirms that macroeconomic factors of the United States of America, the United Kingdom, Japan, China, and India significantly impact gold, silver, and platinum prices. Moreover, Table 4.10 indicates that the prices of precious metals fluctuate in response to changes in macroeconomic factors, which is a significant economic indicator. This evidence is vital for investors, given that precious metals markets are associated with major macroeconomic factors, and this link is crucial for the formulation of global risk management strategies for commercial users and investors of precious metals.

The behaviour of precious metals markets represents valuable information for investors who construct their portfolios using precious metals. However, the results can be extended in a variety of directions. One such direction is the analysis is the period covered by the data, namely 1979–2020, due to the limited availability of data in multiple sources. We have concentrated on data collected monthly. Therefore, future research can repeat this work by focusing on a different sampling period, such as weekly or daily data. Also, our data set only covers the prices of three precious metals, namely gold, silver, and platinum, but the researcher might also include palladium. Finally, we need to investigate the individual impact of macroeconomic factors on the pricing of precious metals in different countries and regions because there is a probability that our results might change after checking country by country. To address this limitation, Chapter 3/Paper 2 of this thesis investigates, explores, and addresses the individual impact of macroeconomic factors on the pricing of four precious metals (gold, silver, platinum, and palladium) in developed and emerging economies.

This study provides the understanding necessary to learn more about the impacts of macroeconomic variables on the returns of the precious metals markets in both developed and emerging economies. Additionally, it provides insight into these five countries' precious metals market conditions. Different techniques and regression analysis have come through lessons with the literature review of the impacts of macro variables on precious metals market returns of these countries over time. The findings of the study have significant policy ramifications. The CPI, IP, SP, SIR, LIR, and UR provide valuable information for predicting the returns of the precious metals markets in developed and emerging countries. These findings provide more support for gold, silver, and platinum investing in protecting against inflation and could assist gold mining companies to help low-income and distant communities access financial products. Furthermore, the central banks of these five economies should ensure that the macroeconomic factors do not disproportionately impact the returns on precious metals markets.

5 Chapter 5: Conclusion

Precious metals are a critical component of any investment portfolio, primarily since their assets are regarded as safe havens by both individual investors and financial institutions. Due to the fact that it is a fundamental aspect of their time allocations, many investors and traders question if these essential commodities are efficiently priced.

The doctoral thesis Chapter 2/Paper 1 reveals that the time predictability of the four metals markets varies throughout the duration. We found that the degree to which re- turns are predictable is determined by the macroeconomic environment, government policies, international events, changes in monetary policies, and the political and eco- nomic conditions that exist at the investment time. There is also evidence that the precious metals markets, like other markets, exhibit periodic deviations from market efficiency, which demonstrates the ramifications of the Adaptive Market Hypothesis (AMH). Predictability and volatility of precious metals returns are observed differently than under normal conditions, particularly during periods of market turbulence and bubble formation. There are several reasons for the movement of capital from capital markets; this may be explained by technical, economic, and speculative strategies used by investors to exploit perceived or real market imperfections.

However, in well-functioning economies, the difference between predicted and actual market returns cannot be consistently exploited as the evidence suggests it is impossible to predict future direction or events due to their level of market efficiencies. Moreover, Chapter 2/Paper 1 suggests that market efficiency for four precious metals varies over time across developed and emerging markets. The variation in market efficiency could be attributable to cyclical economic movements due to technological events such as business boom or bursts. Besides, other psychological and macroeconomic conditions could impact the volatility of precious metals prices. Thus, the interaction between precious metals and the economic environment has important implications. However, such latent factors are not necessarily captured by data used to forecast price movements. This suggests studying precious metals' price movements: there is a need to incorporate soft non-quantitative factors when evaluating precious metals' price movements.

The doctoral Chapter 3/Paper 2 outlines the long-run and short-run relationship between prices of 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) using various cointegration techniques.

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. This study considered the monthly closing prices of precious metals and CPI, IP, SP, LIR, SIR, and UR from January 1979 to September 2020, including 501 maximum and 85 minimum monthly time series observations due to the absence of data for different countries before and after the sample period. The unit root features of the series with and without breaks demonstrate the series' level non-stationarity. By examining the number of cointegrating equations between the variables, the Johansen Trace test with and without breaks, the ARDL model, and the Wald test was used to find the long- and short-run relationships. The appearance of the results varies between experiments, as breaks might skew the utility of typical statistical methodologies.

The findings of Chapter 3/Paper 2 demonstrate cointegrating correlations between monthly prices of precious metals and the CPI, IP, SP, LIR, SIR, and UR over the last forty years, using various econometric tests. The cointegrating correlations in the long run and short run, on the other hand, are highly unstable and vary between developed and emerging economies, showing several structural breaches in the cointegrating relationships during periods of inflation, financial crises, and recession. The findings of Chapter 3 suggested a long-run causal relationship between the prices of gold in Australia, China, India, and Switzerland; silver in India; platinum in the United States, the United Kingdom, and China; and palladium in Australia. However, the gold markets in the United Kingdom, the United States, and Mexico, the silver markets in the United States, the United Kingdom, Switzerland, Mexico, and China, and the platinum market in Australia did not result in any long-term relationships between developed and emerging market economies.

The Wald test was used to determine whether or not explanatory variables in a model are significant and to examine the short-run causality between Dependent and Independent variables, as it predicts short-run causality between dependent and some independent variables, especially in developed economies, as illustrated in Tables 27, 30, 31, and 32. For instance, Gold Japan and Platinum USA have a short-run causality running from Industrial Production (IP) to Gold and Platinum as both metals have a high demand in electronics, computers, dentistry, jewelry medicine, and much more. When the demand for gold in any of these industries fluctuates, it will impact the price of gold. Moreover, the USA auto industry alone would use 48% of global platinum production, and the impact of additional demand on platinum prices would add to the challenge of lowering car costs.

Furthermore, to explore precious metals' short-run inflation hedging ability, this study further revealed that Gold USA, Mexico, and Platinum Australia indicate the short-run causality running from a CPI to Gold and Platinum. These findings show that gold could outperform traditional assets in an inflationary scenario because it is durable, relatively transportable, universally acceptable, and easily authenticated. However, this study found no short-run relationship between precious metals and independent variables in other developed and emerging economies. Furthermore, the short-run causality between short-term and long-term interest rates and gold, silver, and platinum is exclusively observed in the United Kingdom. These findings imply that portfolio managers in the United Kingdom have a greater opportunity to invest in precious metals such as gold, silver, and platinum than in palladium to limit risk during difficult times.

The doctoral thesis Chapter 4/Paper 3 investigates the combined effect of macroeconomic factors (Consumer Price Index (CPI), Industrial Production (IP), Share Price (SP), Long-term Interest Rate (LIR), Short-term Interest Rate (SIR), and Unemployment Rate (UR)) on the pricing of precious metals (Gold, Silver, and Platinum) for developed and emerging economies. We used a panel data regression model to ascertain the significance of and identify the key factors influencing the pricing of the world's most valuable metals. By comparing the macroeconomic impacts of the United States of America, the United Kingdom, Japan, China, and India on precious metals prices, this study determines whether macroeconomic factors in these economies cause precious metals prices to soar or fall and quantifies the magnitude and significance of these effects.

Overall, the analysis of Chapter 4/Paper 3 confirms that macroeconomic factors of the United States of America, the United Kingdom, Japan, China, and India significantly impact gold, silver, and platinum prices. Moreover, the findings indicate that the prices of precious metals fluctuate in response to changes in macroeconomic factors, which is a significant economic indicator. This study contributes to the literature by demonstrating the significance of the precious metal markets and sheds light on the dynamic behaviour of the information transmission in the global metal market system. This evidence is vital for investors, given that precious metals markets are associated with major macroeconomic factors, and this link is crucial for the formulation of global risk management strategies for commercial users and investors of precious metals. The behaviour of precious metals markets represents valuable information for investors who construct their portfolios using precious metals. However, the results can be extended in a variety of directions. One such direction is the analysis is the period covered by the data, namely 1979–2020, due to the limited availability of data in multiple sources. We have concentrated on data collected monthly. Therefore, future research can repeat this work by focusing on a different sampling period, such as weekly or daily data. Also, our data set only covers the prices of three precious metals, namely gold, silver, and platinum, but future researchers might include palladium. Finally, future research should look at the individual impact of macroeconomic factors on the pricing of precious metals in different countries and regions to provide a rich picture of the relationships and their implications.

Overall, this empirical thesis provides a rich analysis of the role of precious metals in Paper -1, 2, and 3 that has implications for practitioners in developing investor's portfolios to mitigate macroeconomic risks. Moreover, the findings of this study imply that macroeconomic fundamentals provide critical insight into the price link between precious metals and that investors may use precious metals differently during periods of economic distress.

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7 Appendix for Chapter 3

This section contains all the unit root test tables.

Table 3.6: Unit Root Tests - Gold Australia

			Level Data: I(0)		First Difference: I(1)	
Variable	Test	Type	Test-statistic	Critical Values	Test-statistic	Critical Values
Gold	ADF	None	1.97	-1.95	-15.85**	-1.95
		Drift	-0.80	-2.87	-15.75**	-2.87
		Trend	-2.09	-3.42	-15.74**	-3.42
	PP	Intercept	-1.06	-2.87	-21.76**	-2.87
		Intercept & Trend	-2.45	-3.42	-21.74**	-3.42
CPI	ADF	None	-1.62	-1.95	-15.69**	-1.95
		Drift	-1.84	-2.87	-15.70**	-2.87
		Trend	-2.63	-3.42	-15.68**	-3.42
	PP	Intercept	-2.16	-2.87	-22.52**	-2.87
		Intercept & Trend	-3.20	-3.42	-22.50**	-3.42
SP	ADF	None	1.79	-1.95	-15.95**	-1.95
		Drift	-2.10	-2.87	-16.22**	-2.87
		Trend	-2.85	-3.42	-19.95**	-3.42
	PP	Intercept	-2.23	-2.87	-20.01**	-2.87
		Intercept & Trend	-3.20	-3.42	-13.11**	-3.42
SIR	ADF	None	-0.80	-1.95	-13.11**	-1.95
		Drift	-2.10	-2.87	-13.25**	-2.87
		Trend	-2.85	-3.45	-13.52**	-3.42
	PP	Intercept	2.27	-2.87	-12.08**	-2.87
		Intercept & Trend	0.55	-3.42	-12.11**	-3.42
LIR	ADF	None	-1.23	-1.95	-12.82**	-1.95
		Drift	1.11	-2.87	-12.95**	-2.87
		Trend	-2.09	-3.45	-13.12**	-3.42
	PP	Intercept	1.48	-2.87	-17.06**	-2.87
		Intercept & Trend	-1.90	-3.42	-17.03**	-3.42
UR	ADF	None	-0.04	-1.95	-14.00**	-1.95
		Drift	-1.34	-2.87	-13.99**	-2.87
		Trend	-1.71	-3.45	-13.97**	-3.42
	PP	Intercept	-1.90	-2.87	-23.32**	-2.87
		Intercept & Trend	-2.36	-3.42	-23.30**	-3.42

Note: (*) = Data is stationarity at level data; (**) = Data is stationarity at first difference. **ADF**: Augmented Dicky Fully Test; **PP**: Phillips-Perron **ADF Critical Values:** None (tau1), Drift (tau2) and Trend (tau3) values are calculated at 5% significance level. **PP Critical Values:** Intercept (Ztau), Intercept & Trend (Ztau) values are calculated at 5% significance level

Table 3.7: Unit Root Tests - Gold Switzerland

			Level Data: I(0)		First Difference: I(1)	
Variable	Test	Type	Test-statistic	Critical Values	Test-statistic	Critical Values
		None	0.99	-1.95	-15.91**	-1.95

Gold	ADF	Drift	-1.31	-2.87	-15.95**	-2.87
		Trend	-1.51	-3.42	-15.93**	-3.42
	PP	Intercept	-1.64	-2.87	-21.76**	-2.87
		Intercept & Trend	-1.83	-3.42	-21.74**	-3.42
CPI	ADF	None	5.91*	-1.95	-	-
		Drift	-6.30*	-2.87	-	-
		Trend	-2.20	-3.42	13.97**	-3.42
	PP	Intercept	-6.54*	-2.87	-	-
		Intercept & Trend	-2.38	-3.42	-19.25**	-3.42
SP	ADF	None	1.82	-1.95	-13.62	-1.95
		Drift	-1.10	-2.87	-13.83**	-2.87
		Trend	-1.77	-3.42	-13.83**	-3.42
	PP	Intercept	-1.07	-2.87	-17.62**	-2.87
		Intercept & Trend	-1.89	-3.42	-20.00**	-3.42
SIR	ADF	None	-1.29	-1.95	-14.30**	-1.95
		Drift	-1.71	-2.87	-14.28**	-2.87
		Trend	-4.10*	-3.45	-	-
	PP	Intercept	-1.94	-2.87	-18.21**	-2.87
		Intercept & Trend	-4.18*	-3.42	-	-
LIR	ADF	None	-0.87	-1.95	-13.25**	-1.95
		Drift	-0.28	-2.87	-13.28**	-2.87
		Trend	-3.11	-3.45	-13.36**	-3.42
	PP	Intercept	-0.45	-2.87	-19.36**	-2.87
		Intercept & Trend	-3.16*	-3.42	-	-
UR	ADF	None	-0.99	-1.95	-9.80**	-1.95
		Drift	-2.44	-2.87	-9.80**	-2.87
		Trend	-2.46	-3.45	-9.83**	-3.42
	PP	Intercept	-1.97	-2.87	-8.13**	-2.87
		Intercept & Trend	-1.90	-3.42	-8.12**	-3.42

Note: (*) = Data is stationarity at level data; (**) = Data is stationarity at first difference. **ADF**: Augmented Dicky Fully Test; **PP**: Phillips-Perron **ADF Critical Values:** None (tau1), Drift (tau2) and Trend (tau3) values are calculated at 5% significance level. **PP Critical Values:** Intercept (Ztau), Intercept & Trend (Ztau) values are calculated at 5% significance level

Table 3.8: Unit Root Tests - Gold Japan

			Level Data: I(0)		First Difference: I(1)	
Variable	**Test**	**Type**	**Test-statistic**	**Critical Values**	**Test-statistic**	**Critical Values**
		None	2.11	-1.95	-11.90**	-1.95

Gold	ADF	Drift	-1.63	-2.87	-12.30**	-2.87
		Trend	-1.23	-3.41	-12.41**	-3.43
	PP	Intercept	-1.88	-2.87	-17.41**	-2.87
		Intercept & Trend	-1.23	-3.43	-18.10**	-3.42
CPI	ADF	None	0.85	-1.95	-10.19**	-1.95
		Drift	-1.01	-2.87	-10.22**	-2.88
		Trend	-1.93	-3.43	-10.29**	-3.43
	PP	Intercept	-0.56	-2.87	-11.23**	-2.87
		Intercept & Trend	-1.68	-3.42	-11.22**	-3.43
IP	ADF	None	0.198	-1.95	-8.31**	-1.95
		Drift	-2.80	-2.87	-8.29**	-2.87
		Trend	-2.96	-3.43	-8.27**	-3.43
	PP	Intercept	-2.82	-2.87	-12.12**	-2.87
		Intercept & Trend	-1.68	-3.42	-12.09**	-3.43
SP	ADF	None	0.42	-1.95	-8.16**	-1.95
		Drift	-1.56	-2.87	-8.14**	-2.87
		Trend	-1.69	-3.41	-8.13**	-3.42
	PP	Intercept	-1.60	-2.87	-11.04**	-2.87
		Intercept & Trend	-1.77	-3.43	-11.00**	-3.43
SIR	ADF	None	-0.68	-1.95	-6.55**	-1.95
		Drift	-0.93	-2.87	-6.53**	-2.87
		Trend	-1.18	-3.41	-6.66**	-3.43
	PP	Intercept	-1.42	-2.87	-11.75**	-2.87
		Intercept & Trend	-1.55	-3.43	-11.78**	-3.43
LIR	ADF	None	-1.29	-1.95	-11.03**	-1.95
		Drift	-1.09	-2.87	-11.08**	-2.87
		Trend	-2.57	-3.41	-11.07**	-3.43
	PP	Intercept	-0.63	-2.87	-12.75**	-2.87
		Intercept & Trend	-2.24	-3.43	-12.77**	-3.43
UR	ADF	None	-2.00	-1.95	-13.14**	-1.95
		Drift	0.30	-2.87	-13.56**	-2.87
		Trend	-1.00	-3.41	-13.66**	-3.43
	PP	Intercept	-0.24	-2.87	-17.56**	-2.87
		Intercept & Trend	-1.33	-3.43	-17.72**	-3.43

Note: (*) = Data is stationarity at level data; (**) = Data is stationarity at first difference. **ADF**: Augmented Dicky Fully Test; **PP**: Phillips-Perron **ADF Critical Values:** None (tau1), Drift (tau2) and Trend (tau3) values are calculated at 5% significance level. **PP Critical Values:** Intercept (Ztau), Intercept & Trend (Ztau) values are calculated at 5% significance level

Table 3.9: Unit Root Tests - Gold United Kingdom

			Level Data: I(0)		First Difference: I(1)	
Variable	**Test**	**Type**	**Test-statistic**	**Critical Values**	**Test-statistic**	**Critical Values**

Gold	ADF	None	1.78	-1.95	-14.89**	-1.95
		Drift	0.29	-2.87	-15.04**	-2.87
		Trend	-1.55	-3.42	-15.12**	-3.42
	PP	Intercept	0.25	-2.87	-21.12**	-2.87
		Intercept & Trend	-1.67	-3.42	-21.2**	-3.42
CPI	ADF	None	9.03*	-1.95	-	-
		Drift	-4.52*	-2.87	-	-
		Trend	-2.92	-3.42	-13.8196	-3.42
	PP	Intercept	-3.94*	-2.87	-	-
		Intercept & Trend	-2.75	-3.42	-19.1735	-3.42
IP	ADF	None	1.22	-1.95	-16.13**	-1.95
		Drift	-3.60*	-2.87	-	-
		Trend	-3.02	-3.42	-15.24**	-3.42
	PP	Intercept	-3.43	-2.87	-25.54**	-2.87
		Intercept & Trend	-3.20	-3.42	-25.68**	-3.42
SP	ADF	None	1.51	-1.95	-14.41**	-1.95
		Drift	-2.11	-2.87	-14.58**	-2.87
		Trend	-2.52	-3.45	-14.61**	-3.45
	PP	Intercept	-2.31	-2.87	-16.67**	-2.87
		Intercept & Trend	-2.54	-3.42	-16.68**	-3.42
SIR	ADF	None	-1.53	-1.95	-10.12**	-1.95
		Drift	-1.02	-2.87	-10.20**	-2.87
		Trend	-2.36	-3.45	-13.26**	-3.45
	PP	Intercept	-1.04	-2.87	-10.64**	-2.87
		Intercept & Trend	-2.41	-3.42	-10.64**	-3.42
LIR	ADF	None	-1.47	-1.95	-12.88**	-1.95
		Drift	-0.50	-2.87	-12.99**	-2.87
		Trend	-3.69	-3.42	-13.04**	-3.42
	PP	Intercept	0.37	-2.87	-12.84**	-2.87
		Intercept & Trend	-2.37	-3.42	-12.84**	-3.42
UR	ADF	None	-2.28*	-1.95	-	-
		Drift	0.74	-2.87	-9.49**	-2.87
		Trend	-1.07	-3.45	-9.47**	-3.45
	PP	Intercept	-1.25	-2.87	-17.26**	-2.87
		Intercept & Trend	-1.70	-3.42	-17.25**	-3.42

Note: (*) = Data is stationarity at level data; (**) = Data is stationarity at first difference. **ADF**: Augmented Dicky Fully Test; **PP**: Phillips-Perron **ADF Critical Values:** None (tau1), Drift (tau2) and Trend (tau3) values are calculated at 5% significance level. **PP Critical Values:** Intercept (Ztau), Intercept & Trend (Ztau) values are calculated at 5% significance level

Table 3.10: Unit Root Tests - Gold United States

	Level Data: I(0)	First Difference: I(1)

Variable	Test	Type	Test-statistic	Critical Values	Test-statistic	Critical Values
Gold	ADF	None	1.74	-1.95	-16.57**	-1.95
		Drift	-0.29	-2.87	-16.72**	-2.87
		Trend	-1.22	-3.42	-16.72**	-3.42
	PP	Intercept	-0.63	-2.87	-23.13**	-2.87
		Intercept & Trend	-1.55	-3.42	-23.11**	-3.42
CPI	ADF	None	6.06*	-1.95	-	-
		Drift	-5.17*	-2.87	-	-
		Trend	-5.30*	-3.42	-	-
	PP	Intercept	-6.08*	-2.87	-	-
		Intercept & Trend	-6.00*	-3.42	-	-
IP	ADF	None	1.88	-1.95	-14.98**	-1.95
		Drift	-1.37	-2.87	-15.19**	-2.87
		Trend	-0.89	-3.42	-15.24**	-3.42
	PP	Intercept	-1.39	-2.87	-17.43**	-2.87
		Intercept & Trend	-0.85	-3.42	-31.95**	-3.42
SP	ADF	None	2.29	-1.95	-14.41**	-1.95
		Drift	-1.72	-2.87	-14.58**	-2.87
		Trend	-2.15	-3.45	-14.61**	-3.45
	PP	Intercept	-1.77	-2.87	-17.43**	-2.87
		Intercept & Trend	-1.86	-3.42	-16.86**	-3.42
SIR	ADF	None	-1.19	-1.95	-13.19**	-1.95
		Drift	-0.62	-2.87	-13.24**	-2.87
		Trend	-2.13	-3.45	-13.26**	-3.45
	PP	Intercept	-1.09	-2.87	-19.02**	-2.87
		Intercept & Trend	-2.71	-3.42	-19.05**	-3.42
LIR	ADF	None	-1.28	-1.95	-12.97**	-1.95
		Drift	1.09	-2.87	-13.14**	-2.87
		Trend	1.09	-3.42	-13.31**	-3.42
	PP	Intercept	2.14	-2.87	-15.30**	-2.87
		Intercept & Trend	0.16	-3.42	-15.29**	-3.42
UR	ADF	None	-0.23	-1.95	-16.18**	-1.95
		Drift	-2.83	-2.87	-16.17**	-2.87
		Trend	-2.89	-3.45	-16.16**	-3.45
	PP	Intercept	-2.72	-2.87	-19.80**	-2.87
		Intercept & Trend	-2.77	-3.42	-19.78**	-3.42

Note: (*) = Data is stationarity at level data; (**) = Data is stationarity at first difference. **ADF**: Augmented Dicky Fully Test; **PP**: Phillips-Perron **ADF Critical Values:** None (tau1), Drift (tau2) and Trend (tau3) values are calculated at 5% significance level. **PP Critical Values:** Intercept (Ztau), Intercept & Trend (Ztau) values are calculated at 5% significance level

Table 3.11: Unit Root Tests - Gold Mexico

			Level Data: I(0)		First Difference: I(1)	
Variable	**Test**	**Type**	**Test-statistic**	**Critical Values**	**Test-statistic**	**Critical Values**
Gold	ADF	None	1.27	-1.95	-17.89**	-1.95
		Drift	-0.87	-2.87	-18.03**	-2.87
		Trend	-4.05*	-3.42	-	-
	PP	Intercept	-0.63	-2.87	-41.65**	-2.87
		Intercept & Trend	-7.81*	-3.42	-	-
CPI	ADF	None	4.35*	-1.95	-	-
		Drift	-4.16*	-2.87	-	-
		Trend	-4.37*	-3.42	-	-
	PP	Intercept	-5.13*	-2.87	-	-
		Intercept & Trend	-6.62*	-3.42	-	-
IP	ADF	None	-0.33	-1.95	-2.76**	-1.95
		Drift	-2.01	-2.87	-3.92**	-2.87
		Trend	-0.67	-3.42	-3.73**	-3.42
	PP	Intercept	-2.40	-2.87	-5.98**	-2.87
		Intercept & Trend	-1.55	-3.42	-6.13**	-3.42
SP	ADF	None	1.43	-1.95	-10.65**	-1.95
		Drift	-1.77	-2.87	-10.91**	-2.87
		Trend	-0.80	-3.45	- 11.078**	-3.45
	PP	Intercept	-1.90	-2.87	-13.03**	-2.87
		Intercept & Trend	-1.77	-3.42	-13.09**	-3.42
SIR	ADF	None	-1.44	-1.95	-9.75**	-1.95
		Drift	-1.85	-2.87	-9.79**	-2.87
		Trend	-1.52	-3.45	-9.87**	-3.45
	PP	Intercept	-2.00	-2.87	-12.83**	-2.87
		Intercept & Trend	-1.60	-3.42	-12.77**	-3.42
UR	ADF	None	-0.12	-1.95	-14.04**	-1.95
		Drift	-1.48	-2.87	-14.01**	-2.87
		Trend	-1.92	-3.42	-13.99**	-3.42
	PP	Intercept	-1.94	-2.87	-23.40**	-2.87
		Intercept & Trend	-2.69	-3.42	-23.34**	-3.42

Note: (*) = Data is stationarity at level data; (**) = Data is stationarity at first difference. **ADF**: Augmented Dicky Fully Test; **PP**: Phillips-Perron **ADF Critical Values:** None (tau1), Drift (tau2) and Trend (tau3) values are calculated at 5% significance level. **PP Critical Values:** Intercept (Ztau), Intercept & Trend (Ztau) values are calculated at 5% significance level

Table 3.12: Unit Root Tests - Gold China

			Level Data: I(0)		First Difference: I(1)	
Variable	Test	Type	Test-statistic	Critical Values	Test-statistic	Critical Values
Gold	ADF	None	0.31	-1.95	-8.32**	-1.95
		Drift Trend	-1.87	-2.88	-8.29**	-2.88
			-2.26	-3.42	-8.27**	-3.42
	PP	Intercept	-2.26	-2.88	-11.72**	-2.88
		Intercept & Trend	-2.61	-3.45	-11.69**	-3.45
CPI	ADF	None	3.23*	-1.95	-	-
		Drift	-1.41	-2.87	-7.29**	-2.87
	PP	Trend	-2.44	-3.43	-13.97**	-3.43
		Intercept	-2.81	-2.87	-9.65**	-2.87
		Intercept & Trend	-2.25	-3.45	-10.20**	-3.45
IP	ADF	None	-3.44*	-1.95	-	-
		Drift Trend	-2.30	-2.88	-8.34**	-2.88
			-1.75	-3.43	-8.62**	-3.43
	PP	Intercept	-0.99	-2.87	-14.25**	-2.87
		Intercept & Trend	-1.84	-3.42	-15.12**	-3.42
SP	ADF	None	-0.26	-1.95	-6.77**	-1.95
		Drift	-2.05	-2.87	-6.74**	-2.87
		Trend	-2.29	-3.43	-6.71**	-3.43
	PP	Intercept	-2.00	-2.87	-7.55**	-2.87
		Intercept & Trend	-2.30	-3.45	-7.51**	-3.45
IR	ADF	None	0.10	-1.95	-7.18**	-1.95
		Drift	-1.82	-2.87	-7.14**	-2.87
		Trend	-2.54	-3.43	-7.33**	-3.43
	PP	Intercept	-1.90	-2.87	-10.20**	-2.87
		Intercept & Trend	-2.34	-3.45	-10.45**	-3.45
UR	ADF	None	-1.04	-1.95	-5.72**	-1.95
		Drift Trend	-2.47	-2.88	-5.79**	-2.88
			-3.58*	-3.41	-	-
	PP	Intercept	-1.92	-2.88	-5.43**	-2.88
		Intercept & Trend	-2.18	-3.45	-5.35**	-3.45

Note: (*) = Data is stationarity at level data; (**) = Data is stationarity at first difference. **ADF**: Augmented Dicky Fully Test; **PP**: Phillips-Perron **ADF Critical Values:** None (tau1), Drift (tau2) and Trend (tau3) values are calculated at 5% significance level. **PP Critical Values:** Intercept (Ztau), Intercept & Trend (Ztau) values are calculated at 5% significance level

Table 3.13: Unit Root Tests - Gold India

			Level Data: I(0)		First Difference: I(1)	
Variable	**Test**	**Type**	**Test-statistic**	**Critical Values**	**Test-statistic**	**Critical Values**
Gold	ADF	None	0.049	-1.95	-7.69**	-1.95
		Drift	-2.51	-2.89	-7.64**	-2.89
		Trend	-2.48	-3.45	-7.65**	-3.45
	PP	Intercept	-2.77	-2.88	-11.67**	-2.88
		Intercept & Trend	-2.68	-3.46	-12.24**	-3.46
CPI	ADF	None	3.51*	-1.95	-	-
		Drift	-2.49	-2.89	-5.46**	-2.89
		Trend	-2.92	-3.45	-5.84**	-3.45
	PP	Intercept	-4.44*	-2.88	-	-
		Intercept & Trend	-2.81	-3.46	-6.80**	-3.46
IP	ADF	None	2.24*	-1.95	-	-
		Drift	0.09	-2.89	-5.46**	-2.89
		Trend	-4.79*	-3.45	-	-
	PP	Intercept	0.30	-2.88	-19.85**	-2.88
		Intercept & Trend	-6.15*	-3.46	-	-
SP	ADF	None	2.29*	-1.95	-	-
		Drift	-0.68	-2.89	-5.99**	-2.89
		Trend	-2.01	-3.45	-5.96**	-3.45
	PP	Intercept	-1.14	-2.88	-9.16**	-2.88
		Intercept & Trend	-2.35	-3.46	-9.09**	-3.46
SIR	ADF	None	-0.65	-1.95	-9.78**	-1.95
		Drift	-2.13	-2.89	-5.99**	-2.89
		Trend	-3.45*	-3.43	-	-
	PP	Intercept	-1.61	-2.89	-8.96**	-2.89
		Intercept & Trend	-3.01	-3.46	-8.90**	-3.46
LIR	ADF	None	-0.48	-1.95	-5.83**	-1.95
		Drift	-1.86	-2.89	-5.81**	-2.89
		Trend	-2.56	-3.43	-5.77**	-3.43
	PP	Intercept	-1.61	-2.89	-5.80**	-2.89
		Intercept & Trend	-2.10	-3.46	-5.75**	-3.46

Note: (*) = Data is stationarity at level data; (**) = Data is stationarity at first difference. **ADF**: Augmented Dicky Fully Test; **PP**: Phillips-Perron **ADF Critical Values:** None (tau1), Drift (tau2) and Trend (tau3) values are calculated at 5% significance level. **PP Critical Values:** Intercept (Ztau), Intercept & Trend (Ztau) values are calculated at 5% significance level

Table 3.14: Unit Root Tests - Silver United States

			Level Data: I(0)		First Difference: I(1)	
Variable	Test	Type	Test-statistic	Critical Values	Test-statistic	Critical Values
Silver	ADF	None	0.48	-1.95	-17.10**	-1.95
		Drift	-0.85	-2.87	-17.11**	-2.87
		Trend	-2.02	-3.42	-17.13**	-3.42
	PP	Intercept	-0.92	-2.87	-23.18**	-2.87
		Intercept & Trend	-1.96	-3.42	-23.24**	-3.42
CPI	ADF	None	6.87*	-1.95	-	-
		Drift	-2.88*	-2.87	-	-
		Trend	-1.30	-3.42	-17.10**	-3.42
	PP	Intercept	-4.34*	-2.87	-	-
		Intercept & Trend	-0.84	-3.42	-22.37**	-3.42
IP	ADF	None	2.00	-1.95	-9.73**	-1.95
		Drift	-2.52	-2.87	-9.89**	-2.87
		Trend	-2.65	-3.42	-10.33**	-3.42
	PP	Intercept	-2.46	-2.87	-19.60**	-2.87
		Intercept & Trend	-0.22	-3.42	-19.59**	-3.42
SP	ADF	None	2.12*	-1.95	-	-
		Drift	-2.15	-2.87	-14.38**	-2.87
		Trend	-2.31	-3.42	-14.52**	-3.42
	PP	Intercept	-2.19	-2.87	-16.13**	-2.87
		Intercept & Trend	-1.96	-3.42	-16.13**	-3.42
SIR	ADF	None	-1.58	-1.95	-10.46**	-1.95
		Drift	-1.10	-2.87	-10.51**	-2.87
		Trend	-2.06	-3.42	-10.49**	-3.42
	PP	Intercept	-1.39	-2.87	-18.43**	-2.87
		Intercept & Trend	-2.57	-3.42	-18.43**	-3.42
LIR	ADF	None	-1.27	-1.95	-12.24**	-1.95
		Drift	1.19	-2.87	-12.46**	-2.87
		Trend	-0.95	-3.42	-12.61**	-3.42
	PP	Intercept	1.87	-2.87	-12.68**	-2.87
		Intercept & Trend	0.53	-3.42	-12.67**	-3.42
UR	ADF	None	-0.05	-1.95	-9.12**	-1.95
		Drift	-2.14	-2.87	-9.09**	-2.87
		Trend	-1.75	-3.42	-9.13**	-3.42
	PP	Intercept	-2.44	-2.87	-19.98**	-2.87
		Intercept & Trend	-2.13	-3.42	-20.05**	-3.42

Note: (*) = Data is stationarity at level data; (**) = Data is stationarity at first difference. **ADF**: Augmented Dicky Fully Test; **PP**: Phillips-Perron **ADF Critical Values:** None (tau1), Drift (tau2) and Trend (tau3) values are calculated at 5% significance level. **PP Critical Values:** Intercept (Ztau), Intercept & Trend (Ztau) values are calculated at 5% significance level

Table 3.15: Unit Root Tests - Silver United Kingdom

			Level Data: I(0)		First Difference: I(1)	
Variable	Test	Type	Test-statistic	Critical Values	Test-statistic	Critical Values
Silver	ADF	None	0.41	-1.95	-15.73**	-1.95
		Drift	-0.73	-2.87	-15.74**	-2.87
		Trend	-2.46	-3.42	-15.75**	-3.42
	PP	Intercept	0.66	-2.87	-21.75**	-2.87
		Intercept & Trend	-2.34	-3.42	-21.79**	-3.42
CPI	ADF	None	9.04*	-1.95	-	-
		Drift	-4.52*	-2.87	-	-
		Trend	-2.92	-3.42	-13.81	-3.42
	PP	Intercept	-3.94	-2.87	-	-
		Intercept & Trend	-2.75	-3.42	-7.25**	-3.42
IP	ADF	None	1.22	-1.95	-16.13**	-1.95
		Drift	-3.60*	-2.87	-	-
		Trend	-3.02	-3.42	-16.37**	-3.42
	PP	Intercept	-3.43*	-2.87	-	-
		Intercept & Trend	-3.20*	-3.42	-	-
SP	ADF	None	1.512	-1.95	-14.41**	-1.95
		Drift	-2.11	-2.87	-14.58**	-2.87
		Trend	-2.52	-3.42	-14.61**	-3.42
	PP	Intercept	-2.31	-2.87	-16.67**	-2.87
		Intercept & Trend	-2.54	-3.42	-16.67**	-3.42
SIR	ADF	None	-1.53	-1.95	-10.11**	-1.95
		Drift	-1.02	-2.87	-10.19**	-2.87
		Trend	-2.36	-3.42	-13.26**	-3.42
	PP	Intercept	-1.05	-2.87	-10.65**	-2.87
		Intercept & Trend	-2.41	-3.42	-10.64**	-3.42
LIR	ADF	None	-1.47	-1.95	-12.88**	-1.95
		Drift	-0.49	-2.87	-12.99**	-2.87
		Trend	-3.69	-3.42	-13.04**	-3.42
	PP	Intercept	0.37	-2.87	-12.84**	-2.87
		Intercept & Trend	-2.37	-3.42	-12.85**	-3.42
UR	ADF	None	-2.28*	-1.95	-	-
		Drift	-0.74	-2.87	-9.48**	-2.87
		Trend	-1.06	-3.42	-9.47**	-3.42
	PP	Intercept	-1.24	-2.87	-17.26**	-2.87
		Intercept & Trend	-1.70	-3.42	-17.25**	-3.42

Note: (*) = Data is stationarity at level data; (**) = Data is stationarity at first difference. **ADF**: Augmented Dicky Fully Test; **PP**: Phillips-Perron **ADF Critical Values:** None (tau1), Drift (tau2) and Trend (tau3) values are calculated at 5% significance level. **PP Critical Values:** Intercept (Ztau), Intercept & Trend (Ztau) values are calculated at 5% significance level

Table 3.16: Unit Root Tests - Silver Switzerland

			Level Data: I(0)		First Difference: I(1)	
Variable	Test	Type	Test-statistic	Critical Values	Test-statistic	Critical Values
Silver	ADF	None	-0.58	-1.95	-16.78**	-1.95
		Drift Trend	-2.01	-2.87	-16.77**	-2.87
			-3.03	-3.42	-16.82**	-3.42
	PP	Intercept	-1.73	-2.87	-23.10**	-2.87
		Intercept & Trend	-2.49	-3.42	-23.32**	-3.42
CPI	ADF	None	5.07*	-1.95	-	-
		Drift Trend	-4.46*	-2.87	-	-
			-1.24	-3.42	-13.19**	-3.42
	PP	Intercept	-4.22*	-2.87	-	-
		Intercept & Trend	-1.20	-3.42	-18.21**	-3.42
SP	ADF	None	1.79	-1.95	-13.01**	-1.95
		Drift Trend	-1.68	-2.87	-13.05**	-2.87
			-1.96	-3.42	-13.09**	-3.42
	PP	Intercept	-1.74	-2.87	-16.66**	-2.87
		Intercept & Trend	-2.05	-3.42	-16.63**	-3.42
SIR	ADF	None	-1.21	-1.95	-14.39**	-1.95
		Drift Trend	-1.19	-2.87	-14.39**	-2.87
			-2.79	-3.42	-14.39**	-3.42
	PP	Intercept	-1.31	-2.87	-16.82**	-2.87
		Intercept & Trend	-3.02	-3.42	-16.81**	-3.42
LIR	ADF	None	-1.07	-1.95	-12.62**	-1.95
		Drift Trend	-0.16	-2.87	-12.67**	-2.87
			-2.75	-3.42	-12.71**	-3.42
	PP	Intercept	-0.29	-2.87	-18.77**	-2.87
		Intercept & Trend	-2.87	-3.42	-18.77**	-3.42
UR	ADF	None	-0.96	-1.95	-9.25**	-1.95
		Drift Trend	-2.53	-2.87	-9.29**	-2.87
			-2.48	-3.42	-9.83**	-3.42
	PP	Intercept	-2.10	-2.87	-7.60**	-2.87
		Intercept & Trend	-1.95	-3.42	-7.61**	-3.42

Note: (*) = Data is stationarity at level data; (**) = Data is stationarity at first difference. **ADF**: Augmented Dicky Fully Test; **PP**: Phillips-Perron **ADF Critical Values:** None (tau1), Drift (tau2) and Trend (tau3) values are calculated at 5% significance level. **PP Critical Values:** Intercept (Ztau), Intercept & Trend (Ztau) values are calculated at 5% significance level

Table 3.17: Unit Root Tests - Silver Mexico

			Level Data: I(0)		First Difference: I(1)	
Variable	Test	Type	Test-statistic	Critical Values	Test-statistic	Critical Values
Silver	ADF	None	1.60	-1.95	-12.58**	-1.95
		Drift Trend	-1.08	-2.87	-12.78**	-2.87
			-1.87	-3.42	-12.77**	-3.42
	PP	Intercept	-1.12	-2.87	-18.15**	-2.87
		Intercept & Trend	-1.87	-3.42	-18.16**	-3.42
CPI	ADF	None	4.36*	-1.95	-	-
		Drift Trend	-4.16*	-2.87	-	-
			-4.37*	-3.42	-	-
	PP	Intercept	-5.13*	-2.87	-	-
		Intercept & Trend	-6.62*	-3.42	-	-
IP	ADF	None	-0.33	-1.95	-2.76	-1.95
		Drift	-2.01	-2.87	-3.92	-2.87
		Trend	-0.67	-3.42	-3.74	-3.42
	PP	Intercept	-2.40	-2.87	-5.98	-2.87
		Intercept & Trend	-1.55	-3.42	-6.13	-3.42
SP	ADF	None	1.43	-1.95	-10.65	-1.95
		Drift	-1.77	-2.87	-10.91	-2.87
		Trend	-0.80	-3.42	-11.08	-3.42
	PP	Intercept	-1.90	-2.87	-13.03	-2.87
		Intercept & Trend	-0.52	-3.42	-13.09	-3.42
SIR	ADF	None	-1.44	-1.95	-9.78	-1.95
		Drift	-1.85	-2.87	-9.80	-2.87
		Trend	-1.53	-3.42	-9.87	-3.42
	PP	Intercept	-2.00	-2.87	-12.84	-2.87
		Intercept & Trend	-1.60	-3.42	-12.77	-3.42
UR	ADF	None	-0.12	-1.95	-14.04	-1.95
		Drift	-1.48	-2.87	-14.01	-2.87
		Trend	-1.91	-3.42	-13.99	-3.42
	PP	Intercept	-1.94	-2.87	-23.39	-2.87
		Intercept & Trend	-2.69	-3.42	-23.34	-3.42

Note: (*) = Data is stationarity at level data; (**) = Data is stationarity at first difference. **ADF**: Augmented Dicky Fully Test; **PP**: Phillips-Perron **ADF Critical Values:** None (tau1), Drift (tau2) and Trend (tau3) values are calculated at 5% significance level. **PP Critical Values:** Intercept (Ztau), Intercept & Trend (Ztau) values are calculated at 5% significance level

Table 3.18: Unit Root Tests - Silver China

Variable	Test	Type	Level Data: I(0) Test-statistic	Level Data: I(0) Critical Values	First Difference: I(1) Test-statistic	First Difference: I(1) Critical Values
Silver	ADF	None	-0.12	-1.95	-7.61**	-1.95
		Drift	-1.38	-2.88	-7.58**	-2.88
		Trend	-2.66	-3.43	-7.60**	-3.42
	PP	Intercept	-1.62	-2.87	-10.75**	-2.88
		Intercept & Trend	-2.70	-3.42	-10.76**	-3.45
CPI	ADF	None	3.23*	-1.95	-	-
		Drift	-1.41	-2.88	-7.2868**	-2.88
		Trend	-2.44	-3.43	-7.433**	-3.43
	PP	Intercept	-2.80	-2.88	-9.65**	-2.88
		Intercept & Trend	-2.25	-3.45	-10.20**	-3.45
IP	ADF	None	-3.44*	-1.95	-	-
		Drift	-2.30	-2.88	-8.34**	-2.88
		Trend	-1.75	-3.43	-8.62**	-3.43
	PP	Intercept	-0.99	-2.87	-14.25**	-2.88
		Intercept & Trend	-1.84	-3.42	-15.13**	-3.42
SP	ADF	None	-0.27	-1.95	-6.77**	-1.95
		Drift	-2.06	-2.87	-6.74**	-2.88
		Trend	-2.30	-3.43	-6.71**	-3.43
	PP	Intercept	-2.00	-2.87	-7.56**	-2.88
		Intercept & Trend	-2.29	-3.45	-7.51**	-3.45
IR	ADF	None	0.10	-1.95	-7.18**	-1.95
		Drift	-1.82	-2.88	-7.14**	-2.88
		Trend	-2.54	-3.43	-7.33**	-3.43
	PP	Intercept	-1.90	-2.88	-10.20**	-2.88
		Intercept & Trend	-2.34	-3.45	-10.45**	-3.45
UR	ADF	None	-1.04	-1.95	-5.72**	-1.95
		Drift	-2.47	-2.88	-5.80**	-2.88
		Trend	-3.58*	-3.43	-	-
	PP	Intercept	-1.93	-2.87	-5.43**	-2.87
		Intercept & Trend	-2.19	-3.45	-5.35**	-3.42

Note: (*) = Data is stationarity at level data; (**) = Data is stationarity at first difference. **ADF**: Augmented Dicky Fully Test; **PP**: Phillips-Perron **ADF Critical Values:** None (tau1), Drift (tau2) and Trend (tau3) values are calculated at 5% significance level. **PP Critical Values:** Intercept (Ztau), Intercept & Trend (Ztau) values are calculated at 5% significance level

Table 3.19: Unit Root Tests - Silver India

Variable	Test	Type	Level Data: I(0) Test-statistic	Level Data: I(0) Critical Values	First Difference: I(1) Test-statistic	First Difference: I(1) Critical Values
Silver	ADF	None	-0.42	-1.95	-6.38**	-1.95
		Drift	-3.29	-2.89	-6.35**	-2.89
		Trend	-2.80	-3.45	-6.63**	-3.45
	PP	Intercept	-3.56*	-2.88	-	-
		Intercept & Trend	-2.98	-3.46	-10.74**	-3.46
CPI	ADF	None	3.51*	-1.95	-	-
		Drift	-2.49	-2.89	-5.46**	-2.89
		Trend	-2.91	-3.45	-5.84**	-3.45
	PP	Intercept	-4.44*	-2.88	-	-
		Intercept & Trend	-2.81	-3.46	-6.81	-3.46
IP	ADF	None	2.24*	-1.95	-	-
		Drift	0.09	-2.89	-5.45**	-2.89
		Trend	-4.79*	-3.45	-	-
	PP	Intercept	0.30	-2.88	-18.52**	-2.88
		Intercept & Trend	-6.15*	-3.46	-	-
SP	ADF	None	2.29*	-1.95	-	-
		Drift	-0.68	-2.89	-5.99**	-2.89
		Trend	-2.01	-3.45	-5.96**	-3.45
	PP	Intercept	-1.14	-2.88	-9.16**	-2.88
		Intercept & Trend	-2.35	-3.46	-9.09**	-3.46
SIR	ADF	None	-0.65	-1.95	-9.78**	-1.95
		Drift	-2.13	-2.89	-9.78**	-2.89
		Trend	-3.45	-3.43	-9.73**	-3.43
	PP	Intercept	-1.61	-2.89	-8.96**	-2.89
		Intercept & Trend	-3.01	-3.46	-8.90**	-3.46
LIR	ADF	None	-0.48	-1.95	-5.82**	-1.95
		Drift	-1.86	-2.89	-5.81**	-2.89
		Trend	-2.57	-3.43	-5.77**	-3.43
	PP	Intercept	-1.61	-2.89	-5.80**	-2.89
		Intercept & Trend	-2.10	-3.46	-5.75**	-3.46

Note: (*) = Data is stationarity at level data; (**) = Data is stationarity at first difference. **ADF**: Augmented Dicky Fully Test; **PP**: Phillips-Perron **ADF Critical Values:** None (tau1), Drift (tau2) and Trend (tau3) values are calculated at 5% significance level. **PP Critical Values:** Intercept (Ztau), Intercept & Trend (Ztau) values are calculated at 5% significance level

Table 3.20: Unit Root Tests - Platinum United States

			Level Data: I(0)		First Difference: I(1)	
Variable	Test	Type	Test-statistic	Critical Values	Test-statistic	Critical Values
Platinum	ADF	None	0.63	-1.95	-11.37**	-1.95
		Drift	-1.55	-2.87	-11.38**	-2.87
		Trend	-1.23	-3.42	-11.41**	-3.42
	PP	Intercept	-1.53	-2.87	-18.60**	-2.87
		Intercept & Trend	-1.17	-3.45	-18.70**	-3.42
CPI	ADF	None	6.42*	-1.95	-	-
		Drift	-1.40	-2.87	-13.81**	-2.87
		Trend	-1.88	-3.42	-13.31**	-3.42
	PP	Intercept	-1.77*	-2.87	-21.66	-2.87
		Intercept & Trend	-1.61	-3.45	-22.37**	-3.42
IP	ADF	None	1.14	-1.95	-12.93**	-1.95
		Drift	-3.13*	-2.87	-	-
		Trend	-2.65	-3.42	-13.23**	-3.42
	PP	Intercept	-3.27*	-2.87	-	-
		Intercept & Trend	-2.59	-3.45	-14.78**	-3.42
SP	ADF	None	1.55	-1.95	-11.80	-1.95
		Drift	-1.92	-2.87	-11.99**	-2.87
		Trend	-2.78	-3.42	-12.02**	-3.42
	PP	Intercept	-1.88	-2.87	-14.22**	-2.87
		Intercept & Trend	-2.66	-3.45	-14.19**	-3.42
SIR	ADF	None	-0.99	-1.95	-10.37**	-1.95
		Drift	-0.74	-2.87	-10.41**	-2.87
		Trend	-1.72	-3.42	-10.42**	-3.42
	PP	Intercept	-1.23	-2.87	-15.62**	-2.87
		Intercept & Trend	-2.27	-3.45	-15.66**	-3.42
LIR	ADF	None	-1.16	-1.95	-10.08**	-1.95
		Drift	0.85	-2.87	-10.26**	-2.87
		Trend	-1.49	-3.42	-10.40**	-3.42
	PP	Intercept	1.87	-2.87	-12.22**	-2.87
		Intercept & Trend	-0.61	-3.45	-12.25**	-3.42
UR	ADF	None	-0.30	-1.95	-14.70**	-1.95
		Drift	-2.65	-2.87	-13.09**	-2.87
		Trend	-2.73	-3.42	-13.09**	-3.42
	PP	Intercept	-2.41	-2.87	-15.79**	-2.87
		Intercept & Trend	-2.48	-3.45	-15.80**	-3.42

Note: (*) = Data is stationarity at level data; (**) = Data is stationarity at first difference. **ADF**: Augmented Dicky Fully Test; **PP**: Phillips-Perron **ADF Critical Values:** None (tau1), Drift (tau2) and Trend (tau3) values are calculated at 5% significance level. **PP Critical Values:** Intercept (Ztau), Intercept & Trend (Ztau) values are calculated at 5% significance level

Table 3.21: Unit Root Tests - Platinum United Kingdom

			Level Data: I(0)		First Difference: I(1)	
Variable	Test	Type	Test-statistic	Critical Values	Test-statistic	Critical Values
Platinum	ADF	None	0.55	-1.95	-13.59**	-1.95
		Drift	-1.52	-2.87	-13.59**	-2.87
		Trend	-1.72	-3.42	-13.58**	-3.42
	PP	Intercept	-1.51	-2.87	-19.74**	-2.87
		Intercept & Trend	-1.63	-3.42	-19.74**	-3.42
CPI	ADF	None	9.48*	-1.95	-	-
		Drift	-4.18*	-2.87	-	-
		Trend	-2.71	-3.42	-13.58**	-3.42
	PP	Intercept	-3.88	-2.87	-	-
		Intercept & Trend	-2.74	-3.42	-25.34**	-3.42
IP	ADF	None	1.21	-1.95	-16.24**	-1.95
		Drift	-3.54*	-2.87	-	-
		Trend	-3.02	-3.42	-16.46**	-3.42
	PP	Intercept	-3.35*	-2.87	-	-
		Intercept & Trend	-3.19*	-3.42	-26.41**	-3.42
SP	ADF	None	1.52	-1.95	-14.52**	-1.95
		Drift	-2.13	-2.87	-14.68**	-2.87
		Trend	-2.51	-3.42	-14.72**	-3.42
	PP	Intercept	-2.30	-2.87	-16.95**	-2.87
		Intercept & Trend	-2.52	-3.42	-16.97**	-3.42
SIR	ADF	None	-1.53	-1.95	-10.11**	-1.95
		Drift	-1.01	-2.87	-10.19**	-2.87
		Trend	-2.35	-3.42	-13.26**	-3.42
	PP	Intercept	-1.04	-2.87	-10.65**	-2.87
		Intercept & Trend	-2.41	-3.42	-10.64**	-3.42
LIR	ADF	None	-1.47	-1.95	-12.88**	-1.95
		Drift	-0.47	-2.87	-12.99**	-2.87
		Trend	-3.65*	-3.42	-	-
	PP	Intercept	0.37	-2.87	-13.03**	-2.87
		Intercept & Trend	-2.37	-3.42	-13.03**	-3.42
UR	ADF	None	-2.32*	-1.95	-	-
		Drift	-0.74	-2.87	-9.55**	-2.87
		Trend	-1.06	-3.42	-9.54**	-3.42
	PP	Intercept	-1.26	-2.87	-17.64**	-2.87
		Intercept & Trend	-1.71	-3.42	-17.63**	-3.42

Note: (*) = Data is stationarity at level data; (**) = Data is stationarity at first difference. **ADF**: Augmented Dicky Fully Test; **PP**: Phillips-Perron **ADF Critical Values:** None (tau1), Drift (tau2) and Trend (tau3) values are calculated at 5% significance level. **PP Critical Values:** Intercept (Ztau), Intercept & Trend (Ztau) values are calculated at 5% significance level

Table 3.22: Unit Root Tests - Platinum Australia

			Level Data: I(0)		First Difference: I(1)	
Variable	**Test**	**Type**	**Test-statistic**	**Critical Values**	**Test-statistic**	**Critical Values**
Platinum	ADF	None	0.84	-1.95	-15.06**	-1.95
		Drift	-1.67	-2.87	-15.10**	-2.87
		Trend	-1.65	-3.42	-15.14**	-3.42
	PP	Intercept	-1.62	-2.87	-22.80**	-2.87
		Intercept & Trend	-1.66	-3.42	-23.02**	-3.42
CPI	ADF	None	-2.21*	-1.95	-	-
		Drift	-3.72*	-2.87	-	-
		Trend	-3.74*	-3.42	-	-
	PP	Intercept	-4.08*	-2.87	-	-
		Intercept & Trend	-4.11*	-3.42	-	-
SP	ADF	None	1.62	-1.95	-12.26**	-1.95
		Drift	-1.83	-2.87	-12.44**	-2.87
		Trend	-2.63	-3.42	-12.47**	-3.42
	PP	Intercept	-2.06	-2.87	-15.51**	-2.87
		Intercept & Trend	-2.77	-3.42	-14.34*	-3.42
SIR	ADF	None	-1.08	-1.95	-11.10**	-1.95
		Drift	-0.92	-2.87	-11.30**	-2.87
		Trend	-0.47	-3.45	-11.49**	-3.42
	PP	Intercept	-2.36	-2.87	-9.09**	-2.87
		Intercept & Trend	1.80	-3.42	-9.16**	-3.42
LIR	ADF	None	-2.37	-1.95	-11.13**	-1.95
		Drift	-1.88	-2.87	-11.29**	-2.87
		Trend	-3.76	-3.45	-11.29**	-3.42
	PP	Intercept	1.80	-2.87	-12.22**	-2.87
		Intercept & Trend	-3.59*	-3.42	-	-
UR	ADF	None	-0.43	-1.95	-12.67**	-1.95
		Drift	-1.27	-2.87	-12.66**	-2.87
		Trend	-0.16	-3.45	-12.80**	-3.42
	PP	Intercept	-1.42	-2.87	-18.84**	-2.87
		Intercept & Trend	-0.73	-3.42	-18.86**	-3.42

Note: (*) = Data is stationarity at level data; (**) = Data is stationarity at first difference. **ADF**: Augmented Dicky Fully Test; **PP**: Phillips-Perron **ADF Critical Values:** None (tau1), Drift (tau2) and Trend (tau3) values are calculated at 5% significance level. **PP Critical Values:** Intercept (Ztau), Intercept & Trend (Ztau) values are calculated at 5% significance level

Table 3.23: Unit Root Tests - Platinum China

			Level Data: I(0)		First Difference: I(1)	
Variable	**Test**	**Type**	**Test-statistic**	**Critical Values**	**Test-statistic**	**Critical Values**
Platinum	ADF	None	-1.35	-1.95	-8.09**	-1.95
		Drift	-0.64	-2.88	-8.26**	-2.88
		Trend	-3.34	-3.43	-8.22**	-3.42
	PP	Intercept	-0.49	-2.87	-14.10**	-2.88
		Intercept & Trend	-4.05*	-3.42	-	-
CPI	ADF	None	3.17*	-1.95	-	-
		Drift	-1.53	-2.88	-8.15**	-2.88
		Trend	-2.75	-3.43	-8.23**	-3.42
	PP	Intercept	-2.72	-2.88	-12.15**	-2.88
		Intercept & Trend	-2.62	-3.45	-13.45**	-3.45
IP	ADF	None	-3.44*	-1.95	-	-
		Drift	-2.31	-2.88	-8.28**	-2.88
		Trend	-1.78	-3.43	-8.55**	-3.43
	PP	Intercept	-0.99	-2.87	-14.09**	-2.88
		Intercept & Trend	-1.83	-3.42	-14.94*	-3.42
SP	ADF	None	-0.26	-1.95	-6.77**	-1.95
		Drift	-2.02	-2.87	-6.74**	-2.88
		Trend	-2.25	-3.43	-6.71**	-3.43
	PP	Intercept	-2.00	-2.87	-7.69**	-2.88
		Intercept & Trend	-2.29	-3.45	-7.65**	-3.45
IR	ADF	None	0.05	-1.95	-7.18**	-1.95
		Drift	-1.75	-2.88	-7.14**	-2.88
		Trend	-2.52	-3.43	-7.33**	-3.43
	PP	Intercept	-1.81	-2.88	-10.20**	-2.88
		Intercept & Trend	-2.32	-3.45	-10.44**	-3.45
UR	ADF	None	-1.04	-1.95	-5.72**	-1.95
		Drift	-2.47	-2.88	-5.80**	-2.88
		Trend	-3.52*	-3.43	-	-
	PP	Intercept	-1.96	-2.87	-5.50**	-2.87
		Intercept & Trend	-2.21	-3.45	-5.41**	-3.42

Note: (*) = Data is stationarity at level data; (**) = Data is stationarity at first difference. **ADF**: Augmented Dicky Fully Test; **PP**: Phillips-Perron **ADF Critical Values:** None (tau1), Drift (tau2) and Trend (tau3) values are calculated at 5% significance level. **PP Critical Values:** Intercept (Ztau), Intercept & Trend (Ztau) values are calculated at 5% significance level

Table 3.24: Unit Root Tests - Palladium United States

Variable	Test	Type	Level Data: I(0) Test-statistic	Level Data: I(0) Critical Values	First Difference: I(1) Test-statistic	First Difference: I(1) Critical Values
Palladium	ADF	None	1.52	-1.95	-13.49**	-1.95
		Drift	-0.16	-2.87	-13.59**	-2.87
		Trend	-2.13	-3.42	-13.62**	-3.42
	PP	Intercept	-0.43	-2.87	-20.75**	-2.87
		Intercept & Trend	-2.62	-3.42	-20.75**	-3.42
CPI	ADF	None	6.32*	-1.95	-	-
		Drift	-2.73	-2.87	-13.32**	-2.87
		Trend	-2.51	-3.42	-13.31**	-3.42
	PP	Intercept	-4.33*	-2.87	-	-
		Intercept & Trend	-2.40	-3.42	-13.32**	-3.42
IP	ADF	None	1.64	-1.95	-- 14.13**	-1.95
		Drift	-2.11*	-2.87	-14.33**	-
		Trend	-1.30	-3.42	-14.52**	-3.42
	PP	Intercept	-2.26*	-2.87	-15.80**	-2.87
		Intercept & Trend	-1.26	-3.42	-15.77**	-3.42
SP	ADF	None	1.78	-1.95	-- 13.31**	-1.95
		Drift	-1.32	-2.87	-13.55**	-2.87
		Trend	-2.25	-3.42	-13.55**	-3.42
	PP	Intercept	-1.45	-2.87	-15.22**	-2.87
		Intercept & Trend	-2.09	-3.42	-15.19**	-3.42
SIR	ADF	None	-1.10	-1.95	-11.66**	-1.95
		Drift	-0.66	-2.87	-11.71**	-2.87
		Trend	-1.84	-3.42	-11.71**	-3.42
	PP	Intercept	-1.20	-2.87	-17.64**	-2.87
		Intercept & Trend	-2.48	-3.42	-17.67**	-3.42
LIR	ADF	None	-1.16	-1.95	-10.08**	-1.95
		Drift	1.01	-2.87	-10.26**	-2.87
		Trend	-1.38	-3.42	-10.40**	-3.42
	PP	Intercept	1.96	-2.87	-12.22**	-2.87
		Intercept & Trend	-0.15	-3.42	-12.25**	-3.42
UR	ADF	None	-0.30	-1.95	-14.70**	-1.95
		Drift	-2.88*	-2.87	-	-
		Trend	-2.85	-3.42	-14.68**	-3.42
	PP	Intercept	-2.69	-2.87	-17.85**	-2.87
		Intercept & Trend	-2.66	-3.42	-17.84**	-3.42

Table 3.25: Unit Root Tests - Palladium Australia

			Level Data: I(0)		First Difference: I(1)	
Variable	Test	Type	Test-statistic	Critical Values	Test-statistic	Critical Values
Palladium	ADF	None	-0.30	-1.95	-14.70**	-1.95
		Drift	-2.87	-2.87	-14.68**	-2.87
		Trend	-2.85	-3.42	-14.68**	-3.42
	PP	Intercept	-2.69	-2.87	-17.45**	-2.87
		Intercept & Trend	-2.66	-3.42	-17.84**	-3.42
CPI	ADF	None	-1.69	-1.95	-12.25**	-1.95
		Drift	-2.97*	-2.87	-	-
		Trend	-3.09	-3.42	-12.22**	-3.42
	PP	Intercept	-3.19*	-2.87	-	-
		Intercept & Trend	-3.36	-3.42	-17.42**	-3.45
SP	ADF	None	1.46	-1.95	-11.06**	-1.95
		Drift	-2.09	-2.87	-11.75**	-2.87
		Trend	-2.87	-3.42	-11.80**	-3.42
	PP	Intercept	-2.07	-2.87	-14.34**	-2.87
		Intercept & Trend	-2.77	-3.42	-14.34*	-3.42
SIR	ADF	None	-1.08	-1.95	-10.27*	-1.95
		Drift	-0.92	-2.87	-10.49**	-2.87
		Trend	-0.47	-3.45	-10.78**	-3.42
	PP	Intercept	-3.63*	-2.87	-	-
		Intercept & Trend	2.10	-3.42	-8.28**	-3.42
LIR	ADF	None	-1.75	-1.95	-9.70**	-1.95
		Drift	-0.30	-2.87	-9.92**	-2.87
		Trend	-1.25	-3.45	-9.97**	-3.42
	PP	Intercept	0.65	-2.87	-12.87**	-2.87
		Intercept & Trend	-0.88	-3.42	-12.83**	-3.42
UR	ADF	None	-0.71	-1.95	-11.98**	-1.95
		Drift	-2.09	-2.87	-11.98**	-2.87
		Trend	-1.17	-3.45	-12.16**	-3.42
	PP	Intercept	-2.15	-2.87	-17.45**	-2.87
		Intercept & Trend	-1.29	-3.42	-17.45**	-3.42

Note: (*) = Data is stationarity at level data; (**) = Data is stationarity at first difference. **ADF**: Augmented Dicky Fully Test; **PP**: Phillips-Perron **ADF Critical Values:** None (tau1), Drift (tau2) and Trend (tau3) values are calculated at 5% significance level. **PP Critical Values:** Intercept (Ztau), Intercept & Trend (Ztau) values are calculated at 5% significance level