THE UNIVERSITY OF HULL

Price Discovery, Market Efficiency and
Temporal Dynamic Price Relationship:
An Empirical Analysis of Worldwide Precious Metals Markets

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Abbreviations

AIC	Akaike's Information Criterion
ADF	Augmented Dickey-Fuller
CBOT	Chicago Board of Trade
COMEX	Commodity Exchange
CME	Chicago Mercantile Exchange
COMEX	Commodity Exchange
EMH	Efficient market hypothesis
HNH	Handy & Harman
LBM	London bullion market
LBMA	London Bullion Market Association
LR	Likelihood Ratio
LME	London Metal Exchange
LPPM	London Platinum and Palladium Market
MLCX	Merrill Lynch Commodity index eXtra
MMI	Major Market Index
NYMEX	New York Mercantile Exchange
OLS	Ordinary Least Squares
OTC	Over the Counter
PP	Phillips-Perron
S&P	Standard and Poor's
SC	Schwarz Criteria
TOCOM	Tokyo Commodity Exchange
VECM	Vector Error Correction Model

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Abstract

The aim of this research is to investigate the price discovery, market efficiency and the temporal dynamic price relationships between financial prices (futures and index) and spot price, for three of the most important precious metals, namely gold, silver and platinum.

When people are concerned about the economy, prudent investors switch their investment into precious metals rather than other asset classes. Precious metals futures, thus, are used by commercial producers and users and investors of precious metals to hedge risk or to make profit on the price fluctuations. Understanding the relationship between markets should foster sensible investment decisions and improve the statistical hedging properties of precious metals.

Inspired by consideration of the unique status of precious metals in the economy and limited existing empirical evidence of price relationship regarding these metals, this research attempts to contribute to the space literature on market efficiency and causality cross three categories of markets—index, futures and spot. Further it will extend the research on price relationships and interactional impacts of precious metals markets based on non-synchronous trading that connects all the major markets around the world.

The findings confirm long-term equilibrium relationships between US futures/index markets and special spot markets of all three precious metals by Cointegration tests. Via VECMs, the findings also revealed that futures prices and indexes of all the tested precious metals played a dominant role in the long run, but not all of them could be the unbiased estimators of the future spot price. On the other hand, mixed results of short-term causality suggested that US futures and indices led spot prices in the majority of cases.

The results from this research supported the hypothesis that futures/indices functioned in the price discovery role in both the long- and short-term, and more importantly, the findings had value implications for market users in decision-making and improving their portfolio performance on precious metal markets.

Chapter 1

Background, Research Objective and Questions

1.1 Introduction

This chapter introduces the background information of this research. Firstly, it gives an overview of the character, production, and market of three precious metals. In particular, it draws a distinction between the important roles of these metals in national and global economies. Next, it reviews the critical perspectives and theoretical framework on the dynamic price relationship between futures markets and spot markets based on recent literature. This is followed by an explanation of the significance and contributions, the motivation and rationale of the study, as well as the research questions and hypotheses. Finally, the structure of the thesis is outlined.

1.2 Overview of Three Precious Metals

Precious metals are important commodities for the world economy. Gold, silver and platinum are considered to be both consumption commodities and investment assets. Each of them has its own unique characteristics in financial terms and in industrial uses. Both gold and silver have been used as monetary media, media of international exchange, and currency for centuries. Meanwhile, they are also used for savings, personal investment, and industrial purposes.

Unlike most other commodities, the saving and disposal of gold are more influential than their consumption on their price movements. Due to the rarity and cost of production, most of the gold ever mined in history is still available. Large stocks of gold are reserved by many central banks or nations as a security of currency and a hedge against financial stress. According to the statistics published by the World Gold Council[1], 19% of all above-ground gold, about 30,000 tonnes, was held by central banks and investment funds as bank reserve assets at the end of 2004. The rest of the gold is being held privately as jewellery, coins and

[1] The World Gold Council is a world's leading gold mining company, and it aims to stimulate demand

bullions. As of October 2009, gold exchange-traded funds held 1,750 tonnes of gold for private and institutional investors, monitored by Goldessential, a London based precious metals advisory company. Physical hoarding of gold bars and investment in financial instrument, such as gold futures contracts are two main forms of gold demand in private investment. As agreed by Hillier et al. (2006), given the comparable size of private-sector gold holdings to total official holding of gold, changes in private investor sentiment play an important role in the gold market. Therefore, due to a limited amount of gold production and it reflects the global nature of the changing markets, gold has been more attractive to investors due to turbulence in the economy.

The silver market is much smaller in value than the gold market. The primary silver supply is as by-products from exploitation of gold deposits. Thus, it results in the price of silver being strongly related to the price of gold. Silver has both physical and financial investment forms. But as further discussed in Hillier's work (2006), silver demand for both private investment and official government reserves are considerably lower than gold. Requirements for silver are dominated by industrial (40% in 2009[2]) and jewellery demands, central bank reserves, and exchange-traded products. As all precious metals, silver may use for store of value and a hedge against inflation and deflation. Unlike gold rarely affected by its consumption, silver is closer to copper or iron, which is consumed in its use. Due to the unique character of silver, such as, the lowest resistivity and highest reflectors of light of industrial metals, silver has been widely used in various manufacture industries. Silver, hence, has a dual role as both an investment and industrial metal, and it is in transition from a precious metal to an industrial metal.

Platinum was discovered far late than gold and silver. It was first referenced in writings was in 16th century and it captured scientists' eyes only from 1748. Its unique properties, it neither tarnishes nor wears out and has an excellent resistance to corrosion can compete with gold. Thus, both gold and platinum are well suited for making fine jewellery. Platinum is more ductile than gold and silver, but less malleable than gold (Weeks, 1968). It also has an extremely high melting point and stable electrical properties. All of these characteristics have been used for industrial applications. Platinum is scarce because of its rarity, and only a few

[2] Statistics is given by the Silver Institution, an international association offers information on silver metal in industrial use, global silver exchange rates, technology, photography, medicine and jewellery.

hundred tonnes is mined annually. Platinum is highly valuable on account of its rarity, high production cost and its essential uses in modern technology. Unlike gold and silver, it is not hold by any central bank or government as a reserve asset, and platinum is used primarily for industrial purposes and traded as a commodity. Of the 245 tonnes of platinum sold in 2010, 46% of them were used for vehicle emissions control devices, 31% for jewellery. The rest went to various other minor applications, such as investment, electrodes, anticancer drugs, oxygen sensors, spark plugs and turbine engines (Loferski, 2011). Hence, approximately two thirds of the total demand for platinum is for industrial uses. Its demand, thus, indicates the wellbeing of the economy, and the changes in price of platinum follow the movements of industrial activity in the long term. And there is less than 10% of its total amount demand in its private investment (Hillier et al., 2006). To be traded physically in commodity markets, such as the London Platinum and Palladium Market, platinum ingots have been assayed and hallmarked in a manner similar to the way gold and silver are.

Moreover, the price of platinum is more volatile than the price of gold. When the economy is stable and growing, the price of platinum surges and tends to be higher than gold price. Whereas, when economy slows down, the price of platinum drops blow than gold price, as demand of platinum decrease for industry falls. In comparison, price of gold is more stable, due to it is used as safe haven and its demand is not driven by industrial uses. On the other hand, because platinum is rarer than gold and with extremely high economic value and volatile price, platinum serves as financial commodity as well. But the size of its market limited by its low production volume.

Both long-run and short-term factors have an influence on precious metals prices. Price movements of precious metals can be affected by changes in the large stocks of held by central banks (like gold and silver) and industrial demands (like silver and platinum). These metals have often been assets purchased as part of portfolio investment (investment commodities), especially in times of rising inflation and global economic and political instability. Meanwhile, investors frequently take short-term speculative positions in precious metals to hedge against perceived risks in the equity and bond markets, and to diversify financial portfolios (Kearney and Lombra, 2009).

1.3 Research Setting

Precious metals of gold, silver and platinum are considered in this thesis due to their unique financial and industrial roles in the modern economies. Their increasing role in both financial and industrial markets has attracted the attention of researchers. However, there is no research focus on a comparable analysis of the investment role of these precious metals in financial markets, until Hillier *et al.* (2006) investigate this issue for gold, platinum, and silver during 1976 to 2004. Their findings suggest that all three precious metals have some hedging capability, particularly during periods of "abnormal" stock market volatility; and these metals may provide diversification within broad investment portfolios that contain precious metals perform significantly better than standard equity portfolios.

The sample period of this thesis is across early 2000s recession to the first half of global financial crisis period, which fermented the global recession starts in 2008. The recession in early 2000s mainly affected developed countries, but it was not as bad as many predicted and the UK, Canada and Australia avoid the recession for the most part. The financial crisis of 2007 to 2008 attacked a number of large financial institutes, stock market, and credit markets in the US, but rapidly developed and spread into a global economic effects. During the financial crisis, credit tightened, consumption, business investment, and international trade declined, along with government spending cut. It results in economies worldwide slowed down, and economies in both developed and developing countries were affected in different extent.

As discussed earlier, precious metals, like gold, silver and platinum, have their own characters and play distinct roles in financial system and manufacture. When economy declines, gold supposes to be a store of value and exert its financial function to stabilize economy and prevent inflation. Similarly, silver is expected to stabilize currency, but as its price is influenced by it industrial demand, a decline in economy may cause its price volatile. Platinum has no effect on financial system and its demand is mainly driven by industrial uses. If production drops, industrial demand in platinum decreases and price of platinum can be extremely volatile.

Hillier *et al.* (2006) use volatility of index and spot price to identify the investment properties of precious metals in US, Europe and Fareast. Data for this thesis derives from world largest trading futures exchange across east and west globe, US indices represent mainstream investors' favourite, and representative precious metal producers, refiners and traders in world market. Due to the global economy turbulence, it would be interesting to take a look at the prediction property of futures and index markets and their interaction with worldwide precious metal spot markets. To pursue this research objective, this thesis focus on the nature of the long-run and short-term price relationships and the predictive power of price movements in futures or index market for those in the spot market.

The investigation in long-run equilibrium relationship is based on the condition that market prices are binding together in the long run, in other words, they are cointegrated in the long run. In the cointegration framework, either one or both markets contribute to the discovery of the equilibrium (efficient) price of the underlying asset, so that a long-run equilibrium between two markets can be reached. The price performs price discovery function via suddenly adjusts market price from previous equilibrium to the new equilibrium by incorporating just arrived information. Hence, the speed at which prices react to new information determines which market price discovery occurs.

Various markets react to new information may vary. When two or more markets do not react to new information identically, one market may lead the other, and the leading market is said to provide price discovery (Du and Hansz, 2009). The essence of the price discovery functions depends on whether new information is reflected first in changed one market price or in changed the other's (Hoffman, 1932). For the markets with less capital required and low cost of transactions, like futures market, have been generally identified having a greater speed of absorbing new information that comes to the markets than the spot markets. Price discovery, thus, is expected to first take place in futures market, and then transmit to its underlying spot markets. This finding suggests that price discovery in futures markets is more efficient than that in spot markets, hence futures prices have predictive power for future movements of its underlying spot price (Peck, 1985, Leuthold et al., 1989). This argument is supported in works by Darrat and Rahman (1995), Pericli and Koutmos (1997), Darrat *et al.* (2002) and others. Since then, the fundamental role of derivatives market is recognized as being a source of price stability, and enable investors effectively to prevent risks in spot markets.

If futures price performs as a forerunner of the spot price, futures market provides a means of hedging protection positions and short-term arbitrage opportunities for commercial users and speculators to more effectively manage price risk of commodities (Buhr et al., 2008, Xu and Fung, 2005). Chassard and Halliwell (Chassard and Halliwell, 1986) state that hedgers in metal futures typically include metal producers and consumers, who use the futures market to protect expected metal market sales against the possibility of declining metal prices. Besides, they also mention that metal refiners can trade in metal futures to protect expected spot market purchases against the contingency of increasing input costs (Chassard and Halliwell, 1986). A major factor for the effectiveness of hedging and speculating operations on a futures market focuses on a close relationship between futures price and its underlying spot price (Garbade and Silber, 1983).

In addition, futures prices are used for pricing spot market transactions and serve as opportunities for portfolio diversification as well. By providing these price signals, futures markets can facilitate a more efficient inter-temporal allocation of real resources via production, inventory or other decisions (Chassard and Halliwell, 1986). Many small and risk averse investors can trade in the spot market without taking the risk of volatility (Raju and Karande, 2003). Therefore, understanding of futures market efficiency is crucial for making optimal hedging and speculation decisions and financial decision on the optimal allocation of portfolios of assets (Lean et al., 2010).

In the market efficiency literature, the hypothesis of futures market efficiency is tested through an examination of whether futures price is unbiased estimators of the future spot price. For instance, in the study of Canarella and Pollard (1985), the hypothesis that the futures price is an unbiased predictor of future spot prices, is employed to analyze the efficiency of the London Metal Exchange for January 1975 to December 1983. Kenourgios and Samitas (2004) suggest the price in efficient markets fully reflects available information, and there is no opportunity for traders to make profit by speculating future spot market price in futures market.

In a (frictionless) perfectly efficient market, the futures price and its underlying spot price should be perfectly correlated. Both of them should fully reflect all available information instantaneously to new information and exist for no lead-lag relationship (Fama, 1970). Meanwhile, no systematic lagged responses long enough to make arbitrage profitable.

However, the contribution of each market to price discovery depends on the microstructure of these markets including the level of transparency, the liquidity supply mechanism, the rules governing the priority of orders, the constraints on short sales and the settlement mechanism (Alphonse, 2000, Tse, 1999). The existence of friction in the markets may result alternative price changes and the two markets do not react at the same time. With lead–lag relationship, market participants filter information relevant to their positions and identify which market may lead the other (Bekiros and Diks, 2008).

While, spot transactions require a greater deal of initial outlay and may take a longer time to implement, spot prices tend to react with a lag (Grossman and Miller, 1988, Miller, 1990). Many studies have been discovered that the changes in futures price dramatically lead that of spot price. It implies that current spot prices are affected by current and past futures prices. Consequently the futures price reflects all information available to market participants and hence, regards as the sign of spot price property. In this case, according to efficient price signals from the markets, informed traders make speculative profits and commercial users make optimal decisions on production, consumption, and marketing (Hasbrouck, 1995, Yang and Leatham, 1999).

1.4 Rationale of the Study

The research objectives of this thesis are to understand the price discovery, market efficiency and price forecasting ability of futures and index markets of precious metals. The spot-futures price relationship is popular topics. A significant number of studies have examined the price relationship, both theoretically and empirically, for a variety of commodities as well as financial assets (Goss, 1985, Husein, 2009). Numerous studies take place on storable commodities but mainly on agricultural commodities (wheat, corn), energy commodities (oil, electricity), and certain numbers of studies carried out on nonferrous metals (albumin, copper). Although most studies have examined nonferrous metals, a majority have not looked at precious metals, such as, gold, silver and platinum.

When all the markets are efficient and prices follow a random walk, markets prices are unpredictable and then investors are difficult to find an edge to make returns from investing. Price movements in spot and futures markets are expected to be correlated, and spot and futures prices should move together across time to avoid arbitrage opportunities. Whereas above average returns are expected to be made by taking advantage of any abnormalities. Hence, understanding market efficiency is very important for investors to inform sensible decisions. Among most empirical investigations on futures-spot price movements, futures prices have been found to respond faster to information than spot prices (Chaihetphon and Pavabutr, 2010). In other words, futures markets are more efficient and lead spot markets to discover efficient price. Meanwhile, the futures price and the expected future spot price are correlated. That is, a causal relationship may exist between markets.

From above, futures markets are informative and transmit information to all market participants; in particular to uninformed producers who may make supply decisions based on futures prices. Physical traders may also use futures prices as a reference to price their commodities due to the greater transparency and greater liquidity of commodity futures over physical commodities. In addition, futures markets are for producers to use to hedge the potential risk of volatile prices and also for speculators who assume greater risk taken in exchange for the opportunity for profit to accept risk. Futures markets, therefore, provide more efficient strategies to improve operational profitability and allocate scarce resources optimally for producers, manufacturers and industrial users of the commodity.

Furthermore, a better understanding of the price relationship among these markets allows inference to policymakers in coordinating the stability of financial markets or imposing price stabilization policies for markets interventions (Soydemir and Petrie, 2003). Besides, indentifying inefficient markets may reflect entry or other barriers or a lack of proper market information and suggest policy interventions in correcting the market system (Lutz et al., 1995).

Based on the existing literature and established price discovery theories, a series of research hypotheses have been developed for reaching the purpose. To begin with, the existence of long-run equilibrium relationship between financial and spot prices for each precious metal is examined by testing the hypothesis of cointegration. If the null hypothesis that two price series are not cointegrated is rejected, both price series cannot wander arbitrarily far away from each other, and then the causality power between two prices can be still identified (He, 1999). Next financial market efficiency is evaluated by the examination of the unbiased predictor hypothesis on cointegrated prices. It suggests futures (or index) markets are more efficient and the futures (or index) markets are the main source of market-wide information (Tse, 1995). The hypothesis of a price discovery role is used to test long-run dynamics of financal prices and spot prices in revealing the efficient price in precious metals markets and futures markets are expected rather than spot markets to be the primary source for price discovery. In addition, short-term price discovery is examined in the lead-lag relationship among these markets, and the question of whether the futures price or index has predictive power over spot prices. Therefore, to test these hypotheses, the following 3 specific research questions have been addressed, based on the unique characteristics of three precious metals.

1. Does the futures market for gold operate efficiently in price discovery for underlying spot markets?

Gold is often used as a reserve asset for government and, as discussed earlier, forming a hedging or diversification tool for private investment portfolios. This states as a reserve asset gold is different from that of silver. Silver has, proportionately a greater industrial demand and significantly higher production levels, but it is used less as a reserve asset. Consequently these different underlying characteristics may mean that silver performs differently to gold. This therefore determines a further research question:

2. Does the futures market for silver operate efficiently in price discovery for underlying spot markets?

Different to gold and silver, platinum is less abundant, its price is more volatile (see chapter 2 for further details) and historically it has not been used as a reserve asset or currency in monetary system. Although platinum does find use in retail and investment portfolios, it is largely used as an industrial metal and mainly demanded for industrial purposes. It thus may suggest different interactions between platinum futures, spot and index markets.

3. Does the futures market for platinum operate efficiently in price discovery for underlying spot markets?

To answer these questions, daily prices of precious metal spot, futures and index markets during 2000 to 2008 are adopted (see chapter 2 for more details). Spot prices in this study are provided by major industrial traders around the world, such as, Perth Mint in Australia, Engelhard in US, and London Bullion Market. Their prices are set as industrial benchmarks. Futures prices are from well developed futures exchanges in US and Japan. And the indexes are from popular investment companies in US. To study the dynamic relationship among precious metal futures price, indexes, spot price is meaningful to assess. Meanwhile, it enhances the liquidity, marketability, operational efficiency, the price discovery function, and the risk-transfer function of main futures markets worldwide, and to perfect futures market's operation mechanism.

Selection of markets based on size and importance in term of their international role of trading, information, and affects on world precious metal prices. Tokyo Commodity Exchange (TOCOM) in Japan, New York Mercantile Exchange (NYMEX) and Chicago Board of Trade (CBOT) of CME Group in US are the largest and most influential metal exchanges in the world. Futures contracts from these exchanges are highly developed, the most active and mature international markets.

Especially interesting is that this research explores the price relationship between futures and spot, and also between index and spot prices. Precious metals indexes from S&P's and Merrill Lynch are included to evaluate the functioning of individual precious metal futures markets. This is achieved by examining whether financial markets with less capital required and low cost of transactions would be more efficient to dominate the spot market, and whether changes in spot price echo changes in financial price.

Moreover, previous studies in this field mainly focus on the relationship between spot futures markets with the same trading hours. There is little research on markets with partial or non-overlapped trading hours. Some markets concerned in this study have different trading hours. Liu and An (Liu and An, 2009) suggest that information transmission in non-synchronous trading markets may exhibit different characteristics. It is hence, particularly interesting to understand whether the findings based on synchronous trading still hold in the markets with non-overlapped or partial overlapped trading hours.

Furthermore, from the international market participants' points of view, this study can provide international exporters/importers of precious metals with some knowledge of the conditions in its international futures and spot markets. As well as arbitrageurs and speculators pay close attention to the pricing relationship of these commodities across global precious metal markets (Liu and Zhang, 2006).

This research, therefore, makes several contributions to existing literature. First, a significantly more comprehensive and recent dataset has been examined in this research. It provides new evidence for the efficiency of futures markets, examining their consistency across beginning periods of economic downturn in 2000s. Second, this study sheds light on which futures market is more important in price discovery and leads global spot markets for these precious metals. Third, this research is inspired by consideration of unique status of precious metals in economy and limited existing empirical evidences of price relationship regarding to these metals. It attempts to contribute to the space literature on market efficiency and causality cross three category markets—index, futures, spot. Meanwhile, it extends the research on price relationships on precious metals markets based on partial and none synchronous trading that connects all the major markets around the world. And their interactional impacts between these inter-linked markets in precious metal markets as well. Fourth, for an empirical perspective, this research is conducted with an emphasis on the international role of fully developed futures markets in price discovery and dynamics of interaction/ interrelation with major commodity traders in the investigated precious metals industry around the world. Price discovery on information linked worldwide markets is of particular importance. Fifth, this study provides updated information to the research on both monetary and industrial precious metal in modern economy. The findings imply current investment activity on precious metals.

1.5 Structure of the Thesis

This thesis is divided into eight chapters and organized as follows. Followed by an introduction, background information and discussion of the precious metal markets, their indexes, futures and spot markets is presented. This includes the characteristics of the concerned precious metals futures contracts and their futures exchanges. Chapter 3 presents a review of antecedent theoretical and empirical literature. It describes strategies used in prior empirical investigations and the methodologies that have been applied. It also outlines the empirical results of existing studies on general storable commodity markets, non-ferrous metal and precious metal markets.

Chapter 4 sets out the appropriate econometric techniques for the investigation of specific causal inference procedures associated with the testable hypotheses. The hypotheses of long-run relationship, market efficiency, and short-run dynamics analysis are estimated to analyze patterns of spot-financial prices in price discovery for three precious metals. An explanation of the preferred econometric models of unit root tests, cointegration approaches and the Vector Error Correction Models, and a discussion of the test procedures is finally stated in Chapter 4.

The empirical results for three precious metals are presented in Chapters 5, 6, and 7 respectively. They include the properties of price series in a preliminary analysis and the empirical results of testing all the hypotheses. Chapter 8 reviews this research as a whole, identifies the points of comparison and contrast of metals and their results, and provides the economic contributions and implications raised from empirical findings. This thesis ends with a discussion of possible avenues for future research.

Chapter 2

Background of Precious Metals Markets and Their Exchanges

2.1Introduction

The futures, index and spot prices of gold, silver and platinum are examined in this research. Gold and silver are commodities that combine the attributes of a currency, financial commodity and general commodity, which is an effective hedge against inflation. According to the CME Group, nations have embraced gold and silver as a store of wealth and a medium of international exchange, and individuals have sought to possess them as insurance against the day-to-day uncertainties of paper money[3]. Both gold and silver are important commodities for investors, particularly in times of economic uncertainty. This uncertainty strongly supports portfolio diversification to protect or expand wealth, and precious metals can be an important part of that diversification. Platinum belongs to the precious metals but with much shorter history in financial and manufacture than both of gold and silver. It is precious is because of its rarity. Platinum is essential to new technology and its supply is largely depend on its demand on its industrial use. Platinum price is very volatile, as any change in economy would reflect on its price.

Futures contracts are hedging tools for commercial producers and users of precious metals against significant price fluctuations in the market, and a way for speculators to make profit of those same price movements in the market. They also serve as a means of global price discovery and opportunities for portfolio diversification, and an alternative investment method to physical gold trading. Futures exchanges offer investors ongoing trading opportunities based on expectations of price, spread or volatility and access to a highly liquid metal market. In particular, trading opportunities provided by platinum futures contracts is extensive due to the price volatility of the metal. Investors benefit from price transparency, which gives all market participants equal access, and the price discovery function of futures market with discovering the real price of gold and reducing the risk of gold markets. in this

[3] Available at http://www.cmegroup.com/trading/metals/files/MetalsRetailBrochure.pdf

research, futures prices of each metal are collected from the world biggest futures organization—CME Group and the futures exchange with most popular precious metal futures contracts in Asia Pacific—the Tokyo Commodity Exchange (TOCOM henceforth).

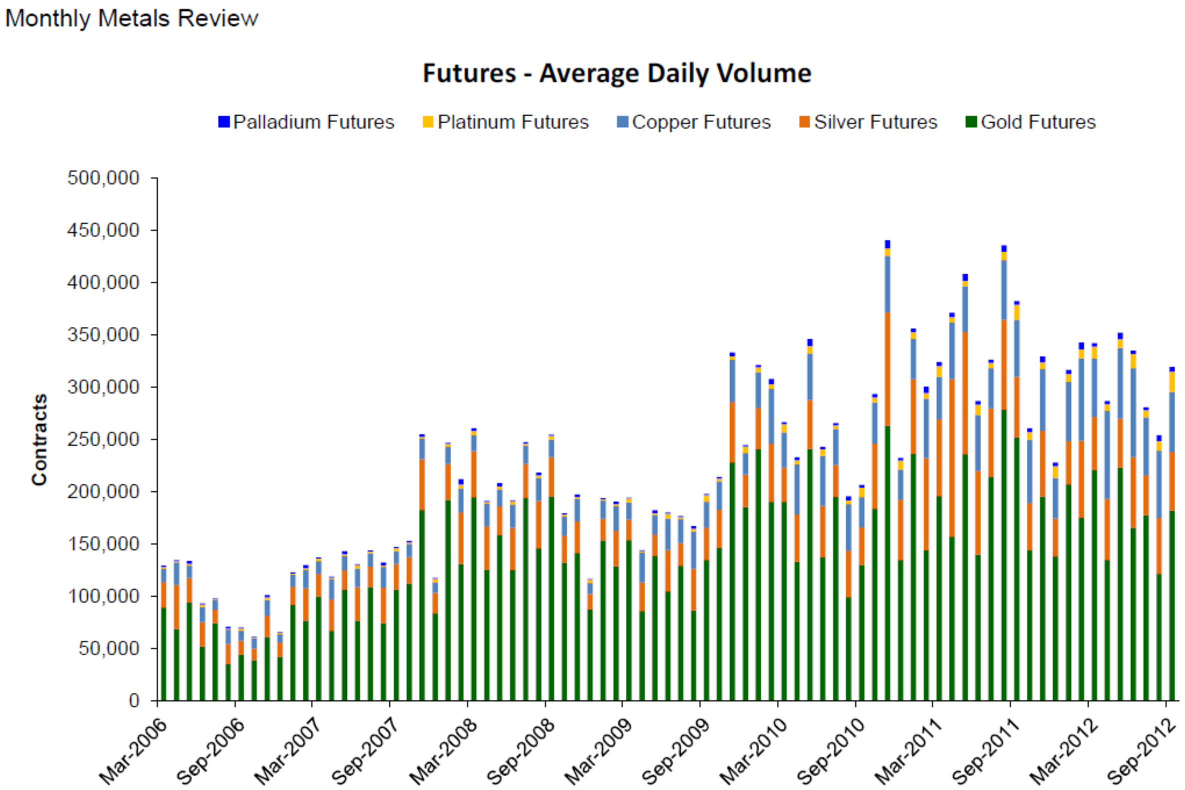
Precious metal index estimates performance of precious metal market over time. It statistically measures changes in a group of precious metals and summarizes movements of each individual in that group in data points. Hence, the precious metal index provides a simple and efficient way to gain exposure to the metal as an assets class. Among the different indexes, only Merrill Lynch Commodity index eXtra and Standard and Poor's (S&P) Goldman Sachs Commodity Index are entirely transparent and publish their underlying commodity selection methods. As an important indicator to investors and leading measure of commodity performance, precious metal indexes from Merrill Lynch and S&P are selected by this research.

Precious metal spot prices are from precious metal producers, refiners and traders who have great contributions to the precious metal industry worldwide. As the quality of their products reach the standard of global precious markets, these products are traded worldwide and their prices have great influence to world precious market. In this section, the background information of the data source is introduced.

2.2Markets of Gold

In this research, precious metal futures price are chosen from three exchanges. The Chicago Board of Trade is the world's oldest futures and options exchange. It took shape to provide a centralized location, where buyers and sellers can meet to negotiate and formalize futures contracts. The New York Mercantile Exchange is the world's largest physical commodity futures exchange, the leading commodity exchange in the US for energy products, metals, and other commodities. CME Group Inc. now owns and operates the Chicago Board of Trade (CBOT henceforth) and New York Commodity Exchange (NYMEX henceforth) and the company offer the largest physical commodity futures marketplace in the world. Therefore, their metal markets bring together a large and diverse community of market participants from around the world to access these highly liquid, highly volatile markets, where buyers and sellers working to protect themselves from price and volatility risk, and investors looking for opportunities. From the world's largest industrial companies to financial institutions, hedge funds, proprietary trading firms and active individual traders, their diverse universe of participants trades an average daily volume of almost 450,000 metals contracts since 2010, as shown in the Figure 2-01 below. It also shows that futures contracts of precious metals traded in CME Group took large proportion of its overall metal trading volume during 2006 to 2012. Among them, gold is the most heavily traded metal, and the average daily volume of gold exceeded 250,000 contracts in few months since 2010.

Figure 2-01 Metals average daily volume in CME Group Mar 2006 – Sep 2012



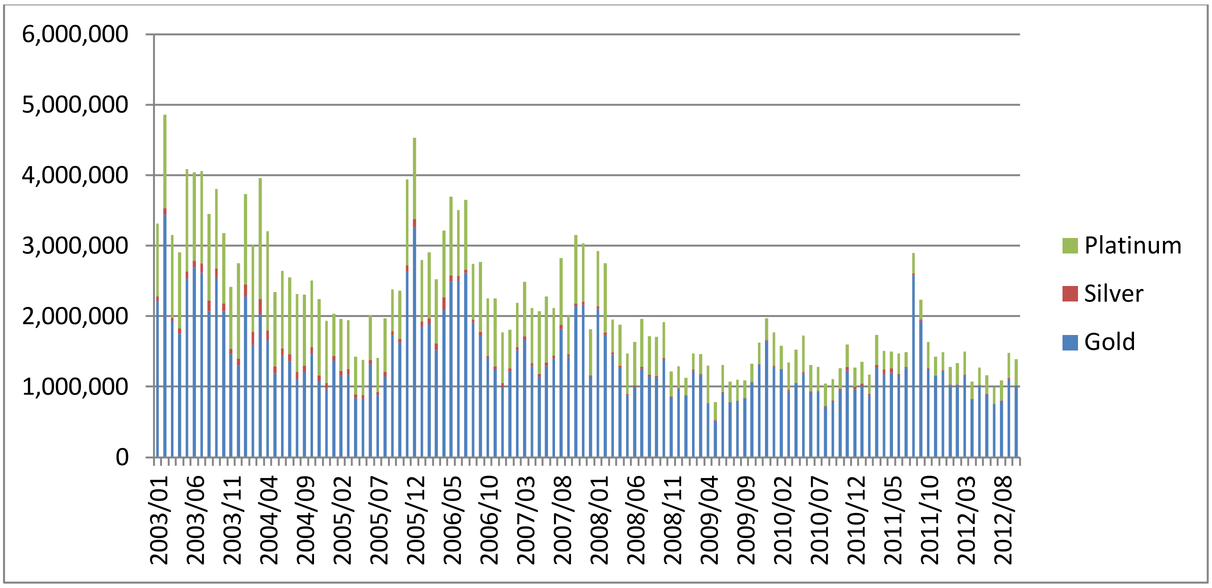
Source: CME Group

Through the merger of three previously existing exchanges, the TOCOM is the broadest, and most diverse, range of commodity futures in Asia Pacific (Banks, 1996). In TOCOM, gold futures were originally introduced in 1982 (on what was then the Tokyo Gold Exchange). The exchange's most active contracts, ranked by trading volume, are its gold and rubber futures.

Figure 2-02 demonstrates that trading volume of gold futures contract TOCOM in August of 2011 also reached high peak, which is similar to the observation to US exchange. However, trading volume of gold and the other two precious metals have decreased since 2008, in compare with US markets, where the trading volume of precious metals has increased. This may caused by the economic decline that made a more significant impact on western markets. And that would be interesting to find out how these futures exchange perform to the change in economy by this research.

Figure 2-01 shows the average daily volume of CME Group and Figure 2-02 shows the average monthly volume of TOCOM. Hence, it implies that the precious metal trading volume on CME Group is much greater than that on TOCOM. It also implies that CME Group is more liquid than TOCOM on precious metal trading.

Figure 2-02 Metals average monthly volume in TOCOM Jan 2003 – Aug 2012



Source: CME Group

Table 2-01 displays the characteristics of gold futures contracts trade at NYMEX in the US and the TOCOM in Japan. They include the trading locations and exchanges, the trading hours, the contract sizes, the deliverable grades and the last trading day of each metal futures contract. It shows that gold futures contracts on TOCOM have higher purity and smaller contract size and longer trading hours than the NYMEX.

Table 2-01

Contract Specifications, Margin Requirements and Liquidity for Gold Futures Contract^{a}

Commodity	U.S.	Japan
Trading location and exchange	New York Mercantile Exchange (CBOT/COMEX divisions)	Tokyo Commodity Exchange (TOCOM)
Trading hours	Monday – Friday 8:20 a.m. - 1:30 p.m.	Monday – Friday 9:00 a.m. - 3:30 p.m.
Contract size	100 troy ounces ≈ 3.11kg	1 kg
Grade and Quality Specifications	Gold of a minimum of 995 fineness	Gold of a minimum 99.99% fineness
Last trading day	Trading terminates on the third last business day of the delivery month	The third business day prior to the delivery day
Listed contract	Trading is conducted for delivery during the current calendar month; the next two calendar months; any February, April, August, and October falling within a 23-month period; and any June and December falling within a 72-month period beginning with the current month	All even months within a year
Initial margin	U.S.$	JPY
Maintenance margin	U.S.$	JPY

Sources: CBOT, NYMEX, TOCOM

a Contract specifications and margin requirements are based on information as of May 2001

b Daily average open interest and volume (in number of contracts) of the nearby futures contract during the sample period from Nov 1994 to Mar 2001

Two indexes from Merrill Lynch and S&P are considered in this research. Merrill Lynch is the world's largest brokerage with a long history on financial investment. The Merrill Lynch Commodity index eXtra (MLCX henceforth) is a rule-driven commodity index where commodity contracts are initially selected by liquidity and then weighted using global production weights, with particular emphasis on downstream commodities. It is composed of commodity index on four precious metals: gold, silver, platinum, and palladium, and that caps 3.9% of all MLCX exposures.

The S&P's GSCI is widely recognized as a leading measure of general price movements and inflation in the world economy. The S&P GSCI is a world-production weighted index that is based on the average quantity of production of each commodity in the index. The weight of each commodity is determined by the average quantity of production. The production weights are designed to reflect the relative significance of each of the constituent commodities in the world economy, while preserving the index's tradability. Such weighting provides the S&P GSCI with significant advantages, both as an economic indicator and as a measure of commodity performance. The S&P GSCI Cash Indices on precious metals, covering gold, silver, platinum and palladium, provide investors with a reliable and publicly available benchmark for investment performance as well as serve as a measure of investment performance in the precious metal commodity markets.

Both of these indexes perform as indictors to investors in precious metal markets, while futures markets are considered as predictor of future spot price, therefore, to assess their ability on price discovery would be useful to investors on decision-making and also other market practitioners to avoid price risks.

Gold spot markets in this research are from Australia, London, Mexico and US. The Perth Mint is responsible for refining all of Australia's gold production and now one of the largest gold refiners in the world. As the mint states, **its total refined gold output reached 4,500 tonnes up to 2000, which accounted for 3.25% of the total weight of gold produced by humankind.** The Perth Mint is a specialist precious metals mint. **The mint** operates as a refiner, weight master and assayer with the London Bullion Market Association (LBMA henceforth), NYMEX, and TOCOM. It also manufactures a wide range of bullion coins and bullion bars made from gold, silver, and platinum for collectors and investors in world markets. Its gold, silver and platinum legal tender coins and bullion bars can be traded without the need for assay. During 1986 to 2001, 85% of precious metal coins made by the mint were sold overseas. Therefore, the spot price of gold, silver, and platinum set by Perth Mint daily has been used as the basis for the pricing of all its wholesale and retail transactions.

Handy & Harman is now a precious metal fabricators and refiners from the US and Canada and it is iconic in US precious metal history. Its precious metal activities include reclamation of precious metals scrap back into use and their alloys into brazing alloys and the utilization of precious metal in precision electroplating. Its profits from precious metal products are derived from the processing and fabricating and not from the purchase and resale of precious metal. The company refines and manufactures gold bars and it has been accredited by New York Mercantile Exchange (COMEX Division) and LBMA.

London always has been an important aggregation for the metals trading since the early decades of 20th century. The London Bullion Market (LBM henceforth) is a wholesale over-the-counter market for the international trading of gold and silver. Members of the LBM are mainly major international banks or bullion dealers and refiners, fabricators and other traders throughout the world. Although the physical market for gold and silver is distributed globally, most wholesale over-the counter are cleared through London. According to LBMA[4], in 2012, an average daily volume of 22.4 million ounces gold cleared and the value of gold ounces transferred is $39.2 billion in LBM.

The London gold fixing or gold fix is the procedure by which the price of gold is determined twice each business day on the London market by the five members of The London Gold Market Fixing Ltd. It is designed to fix a price for settling contracts between members of the LBM. But informally the gold fixing provides a recognized rate that is used as a benchmark for pricing the majority of gold products and derivatives throughout the world's markets.

Mexico is one of the world's largest metal producers with a long mining history. Mexico has the largest epithermal precious metal region in the world and host to the majority of gold and silver deposits in the country. As the table blow shows, the production of Mexico gold mining is increasing in last several years. The increasing production can be leaded by Mexican lowest-cost mining jurisdictions in the world, which is average $325 to produce an ounce of gold compare with average $649 to the rest of world. The prices are set and constantly re-set by the ever-changing supply and demand factors, central banks, miners, dealers, and others who trade in gold almost daily. The gold market amounts to billions of dollars every day, and no one in Mexico would 'set' the price. Gold price in Mexico changes constantly.

Table 2-02 Mexico gold production by year

Year	Production	Unit of Measure	% Change	Year	Production	Unit of Measure	% Change
2002	21324	Kilograms	NA	2006	38961	Kilograms	28.35 %
2003	20406	Kilograms	-4.31 %	2007	39355	Kilograms	1.01 %
2004	21818	Kilograms	6.92 %	2008	50365	Kilograms	27.98 %
2005	30356	Kilograms	39.13 %	2009	51393	Kilograms	2.04 %

Source: United States Geological Survey (USGS) Minerals Resources Program

[4] The London Bullion Market Association is the London-based trade association that represents the wholesale gold and silver bullion market in London.

2.3 Markets of Silver

As gold, silver futures prices are from the CME Group and the TOCOM where precious metal contracts commonly trade on. From above figure 2-01 and 2-02, it shows that trading volume of silver contracts in the CME Group is more than it has on the TOCOM. Table 2-03 shows that two contracts have the same purity of silver, but TOCOM's silver contract size is smaller than CME Group's.

Table 2-03

Contract Specifications, Margin Requirements and Liquidity for Silver Futures Contract[a]

Commodity	U.S.	Japan
Trading location and exchange	New York Mercantile Exchange (CBOT/COMEX devisions)	Tokyo Commodity Exchange (TOCOM)
Trading hours	Monday – Friday 8:25 a.m. - 1:35 p.m.	Monday – Friday 9:00 a.m. -3:30 p.m.
Contract size	5000 troy ounces ≈ 155.5 kg	30 kg
Grade and Quality Specifications	Silver of a minimum of 999 fineness	Fine silver of minimum 99.99% fineness
Last trading day	Trading terminates on the third last business day of the delivery month.	The third business day prior to the delivery day
Listed contract	Trading is conducted for delivery during the current calendar month; the next two calendar months; any January, March, May, and September falling within a 23-month period; and any July and December falling within a 60-month period beginning with the current month.	All even months within a year
Initial margin	U.S.$	U.S.$
Maintenance margin	U.S.$	U.S.$
Open interestb		
Volumeb		

Sources: CBOT, NYMEX, TOCOM

a Contract specifications and margin requirements are based on information as of May 2001

b Daily average open interest and volume (in number of contracts) of the nearby futures contract during the sample period from Nov 1994 to Mar 2001

As the same considerations of gold indexes, silver indexes are chosen from Merrill Lynch's MLCX and S&P's GSCI that silver is composed of these indexes. These indexes indicate the performance of silver investment and that would affect on decision-making of silver investors. The spot prices of silver for this research are from the same source as gold's. Apart from refining gold, the Perth Mint in Australia also issues the world's largest range of pure silver investment bullion bars and coins for investors to trade internationally. The mint's silver products are recognised by the LBMA, which means they can be traded internationally without the need to assay. Handy & Harman has a long tradition in the refining of silver, and has become the largest silver trading firm in US. According to the company’s annual report in 2011, its precious metal segment net sales increased by $62.2 million, or 48.5%, to $190.6 million for the twelve months ended December 31, 2011, as compared to $128.4 million in 2010. The increase was primarily driven by higher sales resulting from increased silver prices and more units sold. Handy & Harman's daily silver price quotation has long since become independent of London. Today it represents simply the lowest price at which, on any given day, Handy & Harman can buy silver for its own needs and this price is accepted as a guide for silver transactions worldwide.

London is one of the most important aggregations for the metals traders from all over the world. Silver is traded at LBM, where a daily average of 124.3 million ounces silver transferred and the value of silver ounces transferred reach $4.18 billion. London Silver Fixing started earlier than the London Gold Fixing, which marked the beginning of the market’s structure and of the co-operation between members that has created the marketplace as it is today. For almost a century, the fixings are the internationally published benchmarks for precious metals. They are fully transparent and provide market users, such as producers, consumers, investors and central banks with the opportunity to buy and sell gold or silver in large amounts at an accepted average price of the metal. Therefore, it would be interesting to find the relationship between LBM and world financial markets.

Historically, Mexico has been the world's largest silver producer. According to the Silver Institute[5], today the country remains the leading producer of silver with a historic production records exceed 15 billion ounces of silver in 2011, which offers 20% of world’s production. The US is the main export market for Mexico’s metals, which is receiving more than half of Mexico’s silver export in 1990s (Barnhart, 1993). Mexico’s ever-expanding gold mining industry is well positioned for a strong year in 2010, with output expected to increase by an additional 880,000 ounces to nearly 2.5 million ounces [6]. And that represents an approximately 50% increase over projected figures in 2009. In the early 90's, Mexico overhauled its mining structure to attract foreign mining investment, and the foreign

[5] A nonprofits international association that serves as the industry's voice in understanding silver
[6] The Chamber of Mines of South Africa in 1920
http://www.randrefinery.com/newsletters/RRL_Daily_Gold_Report_20100901.pdf

investment has been allowed since. There is no fixed price in Mexico, which means the price is decided by supply and demand.

2.4 Market for Platinum

As gold and silver, platinum futures prices are from the CME Group and the TOCOM as well. It is interesting to find from figure 2-01 and 2-02 that platinum contracts are traded more in TOCOM but very few in CME Group. It just opposites to the trading volume of silver traded in these two exchanges. Table 2-04 shows that platinum purity are the same from two contacts but TOCOM platinum contract size is smaller.

Table 2-04

Contract Specifications, Margin Requirements and Liquidity for Platinum Futures Contract^{a}

Commodity	U.S.	Japan
Trading location and exchange	New York Mercantile Exchange (NYMEX)	Tokyo Commodity Exchange (TOCOM)
Trading hours	Monday – Friday 8:20 a.m. - 1: 05 p.m.	Monday – Friday 9:00 a.m. -3:30 p.m.
Contract size	50 troy ounces	500 g
Deliverable grades Fine gold of minimum	Fine platinum of minimum 99.95% purity	Fine platinum of minimum 99.95% fineness
Last trading day	The third business day prior to the end of the delivery month	The third business day prior to the delivery day
Listed contract	Trading is conducted over 15 months beginning with the current month and the next two calendar months before moving into the quarterly cycle of January, April, July, and October.	All even months within a year
Initial margin	U.S.$	JPY
Maintenance margin	U.S.$	JPY
Open interest		
Volume		

Sources: CBOT, NYMEX, TOCOM

a Contract specifications and margin requirements are based on information as of May 2001

b Daily average open interest and volume (in number of contracts) of the nearby futures contract during the sample period from Nov 1994 to Mar 2001

Platinum indexes are from Merrill Lynch's MLCX and S&P's GSCI that platinum is composed of these indexes. A comparison with price discovery function of platinum futures prices can be useful to investors on managing risk and make optimal decision. Platinum price from Perth Mint is considered in this research. With standard quality of platinum bars and coins, the mint refines platinum for traders and investors from international markets. The base price is set by the mint, which excludes any additional charge; hence, it is used as a benchmark to metal transaction of retail and wholesale. Engelhard used to be the world's largest refiner and fabricator of platinum metals, gold and silver. It is now part of the Metal Services Group and trades in precious metals on behalf of the BASF Group since after takeover in 2006. The BASF Group is one of the world’s largest users of platinum group metals, and, as a result, there are times when it holds large industrial commodity positions that are subject to market price fluctuations. The current role of Engelhard, now renamed to BASF Metals Limited, is to centrally monitor, hedge and mark-to-market daily the fluctuations in price risks to which BASF is exposed in the metals markets. Therefore, platinum price given by Engelhard has impact on metal market price and that brought research interest in this price.

As gold and silver are traded on LBM, platinum is traded on London Platinum and Palladium Market (LPPM henceforth). London has historically been an important centre for the discovery, research in, and development of most of the Platinum Group Metals (McDonald and Hunt, 1982). The main physical market indulging in the trade of platinum is LPPM. Leading organisations dealing in platinum and palladium in major centres worldwide are represented on the London Market.

Four members of the LPPM fix the bid prices of the varying metal price twice each day. The fix prices, also known as the London Fix provides, are considered a benchmark in detecting world platinum prices. Bid prices in turn affect the offer prices that customers are asked to pay for metal. The market values of platinum and palladium, as is the case for all commodities, ultimately affect manufacturing costs. In effect, the fixing price represents matched orders from customers across the world to buy or sell. The fixings make it transparent to interested parties: supplier, consumer, dealer or investor, the price at which all current dealings have been satisfied (Kendall, 2004). Because of the importance of the LPPM and its platinum price to the world platinum market and price, platinum price at the LPPM is chosen by this research.

As Weston (1984) states that free market in physical platinum is operated by dealers in New York, London, Zurich, Germany and Japan. The free market caters for consumer shortfalls and excess inventories and provides an outlet for recovered scrap. According to the report by US Bureau of Mines[7], although the volume of mineral commodity free market sales has varied over time and free market prices sometimes change very rapidly. Dealers in the free market and consumers of platinum could, and did, use the futures market for hedging purposes and there were sufficient speculators and arbitrageurs to ensure a continuous market. Therefore, platinum price of free market in New York is selected for this research to find out if the major platinum futures prices and indices benefit free market participants.

[7]Available at http://s3.amazonaws.com/zanran_storage/minerals.usgs.gov/ContentPages/30647221.pdf

CHAPTER 3

Review of Studies on Futures Prices, Their Roles and Interactions with Spot Market

Since the emergence of the derivative market and further development in futures trading, the spot-futures markets linkage for various commodities as well as for financial assets has been and continues to be an active area of extensive empirical research. The price dynamics between futures and its underlying spot prices has been examined to discover the linkage between these two markets, by focusing on price discovery, market efficiency, and causal relationship between futures and spot prices in literature on this research field.

These issues explore general relationship between futures and future spot prices, examine price discovery function of futures prices on future spot prices, reveal whether futures prices fulfil their price discovery function, and identify the causal relationship between futures and spot markets. The related existing literature has covered a wide range of commodities, such for instance, Schwartz and Szakmary (1994) have discovered the cointegration relationship between futures and spot prices for petroleum markets, Bessler and Covey (1991) examine cointegration in US cattle markets; Figuerola-Ferretti and Gilbert (2005) investigate the price discovery in the Aluminium market; Moosa (2002) examine the price discovery in the crude oil futures market; Fortenbery and Zapata (1997) evaluate the price futures-spot markets linkages for cheddar cheese; Silvapulle and Moosa (1999) investigate the futures-spot relationship in the crude oil markets. The general questions appear in literature are:

whether there is a long-run relationship between two markets;

whether one market has influence on the other one;

whether futures markets fulfil the price discovery function maintain long-term equilibrium;

whether futures prices provide an accurate/unbiased forecasting of future spot prices;

whether futures prices lead the underlying spot prices and forecast the future spot prices

Futures contracts are developed as financial instruments for price discovery, risk transfer or hedging. The use of futures contacts provides investors forecasting on future spot prices, flexibility on portfolio synthesis and rapidity in transactions; minimizing portfolios risk, protect commodity traders on prices and supply of the commodity against drastic price fluctuations in spot markets. Understanding spot-futures markets relationship provides benefits to markets participants from different categories. It provides an insight of hedging effectiveness and speculation and arbitrage opportunities in futures markets for investors to makes optimal investment strategies. A better understanding of their relationship coordinates government policymakers on the stability of financial markets. Moreover, when futures prices provide a reliable forecast of future spot prices, producers and international exporters and importers of commodities make better production and consumption decision that leads to an optimal allocation of scarce resources (Manfredo and Sanders, 2008).

As the increase on the correlation of regional and global business, investors now are considering on the various types of assets across different countries, thus, an understanding on linkage among international markets is becoming important and attracts attention from academics and practitioners. Current literature on this area is primarily addressed on the international equity markets, such as, Eun and Shim, 1989; Susmel and Engle, 1994; Koutmos and Booth, 1995, Booth, Lee and Tse; 1996. Most of these studies are focused on markets in developed countries, for instance, Eun and Shim (1989) find US equity market transmits information to foreign markets; Koutmos and Booth (1995) investigate the dynamic interaction between stock markets of New York S&P 500 and London FTSE 100; Booth, Lee and Tse (1996) discover the international linkages in the Nikkei stock index futures markets.

Fewer recent studies are on international commodity markets for agricultural and metal commodities. Booth and Ciner (1997) look at international corn futures markets; Booth et.al (1998) have checked the wheat futures markets relationship between US and Canada; Fung et.al (2003) investigate the commodity futures trading between US and China; Xu and Fung (2005) examine the cross-market linkages between US and Japanese precious metals futures trading.

By systemically reviewing existing literature, the aim of this research to investigate price discover, market efficiency, long-run and short-term price relationship between financial price (futures price and index) and spot price for precious metals is explicit. Its findings are important since no previous study has addressed on it.

3.1 Overview of Literature on Cointegration

Futures and spot prices with cointegration relationship have a tendency to move together in the long-run. It implies that futures and spot markets are correlated with a long run equilibrium relationship and spot and futures prices are predictable (Ghosh, 1993). Cointegrated futures and spot prices discover equilibrium prices by price adjustments in the long run and allow short term deviations from their common equilibrium path (Cho and Ogwang, 2006). The research question on whether two markets are in the long-run relationship is important, as the price discovery role and the causal relationship between prices are able to test on cointegrated markets.

An overwhelming number of studies have examined long-run relationships between futures and spot markets, both theoretically and empirically, for many commodities; such as, prior studies by Garbade and Silber (1983), Hill, Schneeweis and Yau (1990), Fung and Lo (1995), Lihara, Kato, and Tokunaga (1996), Quan (1992); Schwartz and Szakmary (1994); Covey and Bessler (1995); Karbuz and Jumah (1995).

Cointegration analysis is used to investigate the empirical long-run relationship between spot and futures prices. Johansen's (1991, 1988a) approach has been widely applied since then on research in relation to different commodities, for example, the futures and spot prices relationship is investigated by cointegration theory earlier in study of Lai and Lai (1991) to currency markets; in studies of Mckenzie and Holt (1998), Kellard et al. (1999) and Yang et al. (2001) on agricultural commodity markets; and in study of Haigh (2000) on freight market.

Meanwhile, cointegration framework developed by Engle and Granger (1987) has also been adopted to test cointegration by researchers, such as, MacDonald and Taylor (1988) use this approach test on metal futures markets, Chowdhury (1991), Spehton and Cochrane (1991), Moore and Cullen (1995) and Chen and Lin (2004) test on non-ferrous metals traded in London Metal Exchange, Krehbiel and Adkins (1993) test on interest rate.

In commodity markets, Jones and Uri (1990) find prices for three non-ferrous metals markets in US are cointegrated using both cointegration framework and correction mechanism. Chowdhury (1991) examined the cointegration relationship between colour metal futures price and spot price. Fortenbery and Zapata (1993) find corn and soybeans spot and futures contracts are cointegrated. Yang and Leatham (1999) test long-term relationship on both the three spot prices and the three US futures prices of wheat respectively by utilising the Johansen's trace cointegration test. They find the price discovery function performed poorly for the US wheat spot markets.

Cointegration has been found in studies of indexes stock markets (see, Epps, 1979, Cerchi and Havenner, 1988, Takala and Pere, 1991, Bachman et al., 1996, Choudhry, 1997, Crowder and Wohar, 1998, Chan and Lai, 1993, Ahlgren and Antell, 2002). Fung and Leung (1993) discover that spot and futures prices are cointegrated in the Eurodollar market. Tse (1998) found cointegration of international Euromark futures markets using the Johansen's (1988a) approach.

There is evidence of absence of cointegration for non-financial commodities in empirical research. Baillie and Myers (1991) test a number of agricultural commodities markets; Covey and Bessler (1995) study live cattle markets, Schroeder and Goodwin (1991) study live hogs markets; Krehbiel and Adkins (1993) study metals markets; Crodwer and Hamed (1993) investigate oil futures markets. Other sources reported absence of cointegration between spot and futures prices for many other commodities. Thus, the cointegration test results are not consistent and difficult to explain. In this case, it seems that futures prices and spot prices may be determined separately, and so it seems unlikely for futures prices to be an unbiased predictor of future spot prices

Markets in the traded assets are fundamentally related to each other (Liu and An, 2009). According to Engle and Granger (1987), prices for the same commodity in different spatial markets may be expected to move together, i.e., cointegrated, although they may individually wander extensively. If prices in different spatial markets are fully cointegrated with one price, this cointegration provides direct evidence for perfect price discovery in the long-run (Yang and Leatham, 1999).

Even these markets are linked, they may have different information processing abilities and contributions to price discovery due to the distinctions in their transaction costs, regulations, liquidities, and other institutional factors (Liu and An, 2009). Understanding the behaviour and price effects of futures and spot trading in different world markets is of great significance to brokerage houses, investors, portfolio managers, regulators, legislators and the major global stock and futures exchanges (Bose, 2007).

The price relationships between two informationally linked markets, such as spot and futures markets, domestic and overseas futures markets has been investigated in a number of studies (see, Kawaller et al., 1987, Stoll and Whaley, 1990, Tse, 1999, Wahab and Lashgari, 1993, Hasbrouch, 1995, Gonzalo and Granger, 1995, Lihara et al., 1996, Roope and Zurbruegg, 2002, Xu and Fung, 2005, Ding et al., 1999).

Limited cointegration based studies are conducted on price relationships across spatial spot commodity markets. Some inferences draw on price discovery function in spot markets from previous studies. The earlier works suffer some econometric shortcomings, such as ignoring non-stationary properties of the analyzed variables and inappropriate application of price difference modelling (Ardeni, 1989, Schroeder and Goodwin, 1991).

Investigation by Jung and Doroodian (1994) prove the hypothesis of a single long run equilibrium price for four US regional softwood lumber markets. Silvapulle and Jayasuriya (1994) investigate that the Philippines rice spatial markets are well integrated in the long run. Lutz et al. (1995) find diverse evidence for one equilibrium price across each pair of several spatially separated maize markets in Benin. These studies suggest that spatially isolated spot markets in some cases may function well in commodity price discovery.

More research has been taken to explore price discovery across spatially different futures markets for an asset. In equity markets, Booth, Lee, and Tse (1996) have investigated the relationship among the cross exchange prices of Nikkei 225 Index futures that are traded in Singapore, London and Chicago is cointegrated. Tse (1998) investigated the Eurodollar futures markets in Chicago, Singapore, and London and found that all these markets are cointegrated by a common factor.

In commodity markets, Long and Wang (2009) review a number of significant research that relate to futures market between China and abroad. Booth et al. (1998) reveal a cointegration relationship between the prices of wheat futures contracts traded in the Chicago Board of Trade (CBOT) and the Winnipeg Commodities Exchange (WCE) of Canada. Zhao (2004) shows a cointegration relationship between China's metal futures price and international futures price. Cointegration relationship between copper futures price of Shanghai, China and that of London, UK has been found in empirical researches by Gao (2004, 2005).

3.2 Overview of Literature on Testing Price Discovery

Price discovery refers to the impounding of new information into the price (Tse 1999). If new market information disseminates in the futures market before the spot market, then the introduction of a futures markets increases the amount of information reflected in the spot price (Ryoo and Smith, 2004). Futures prices, thus, are considered to fulfil the price discovery role, and can be used for pricing spot market transactions and discovering present and future equilibrium prices (Pizzi et al., 1998).

Booth et al. (1996) suggest that higher transaction costs may reduce market information efficiency. Highly liquid, low transaction costs, easily available short positions, low margins and rapid execution of futures market may lead futures markets to be more efficient than their corresponding spot markets (Kavussanos and Nomikos, 2003). Price discovery is expected to first take place in the futures market and then it is transmitted to underlying spot market due primarily to relatively lower transaction costs of the futures markets (Pizzi et al., 1998, Du and Hansz, 2009). Therefore, spot prices tend to react with a lag and led by futures markets.

Studies examine the price discovery function in various financial futures markets, such as, on T-bill rates MacDonald and Hein (1989, 1993), interest rate (Krehbiel and Adkins (1994). But mainly in relation to stock index futures, in particular US stock markets (see, Kawaller et al., 1987, Stephan and Whaley, 1990, Chan, 1992, Grünbichler et al., 1994, Hasbrouck, 1995, Pizzi et al., 1998, McMillan, 2005). Price discovery in worldwide stock markets has also attracted academics attentions, for instance, in German stock markets (Booth et al., 1999), Hong Kong's stock market (So and Tse, 2004), Korean stock market (Ryoo and Smith, 2004), Spanish stock market (Lafuente, 2002), Greek (Floros and Vougas, 2007), and Indian stock market (Pradhan and Bhat, 2009, Tenmozhi, 2002).

Price discovery function of futures markets has also been investigated for various commodity market, such as, Canadian agricultural markets (Khoury and Yourougou, 1991), grain market (Fortenbery and Zapata, 1993), metal markets (Fama and French, 1988). And the existing studies cover a wide range of agricultural and metal commodities, for example, corn, wheat, oats, orange juice, copper, gold and silver (Garbade and Silber, 1982), cheddar cheese (Fortenbery and Zapata, 1997), Chinese soybean and wheat (Liu and Zhang, 2006), crude and heating oil (Schwarz and Szakmary, 1994); crude oil (Silvapulle and Moosa, 1999, Moosa, 2002), aluminium (Figuerola-Ferretti and Gilbert, 2005b), Indian gold market (Chaihetphon and Pavabutr, 2010).

The question of which market dominates in price discovery has a long time debate in empirical literature, which began with Garbade and Silber (1982). Empirical evidence to date shows mixed results of testing for the primary role of price discovery. Stein (1961) finds that futures and spot prices for a given commodity move in a synchronous pattern. Yang et al. (2001) conclude that storable futures commodity prices are at least equally important as informational sources as the spot prices via Vector Error Correction Model estimation. Quan (1992) finds that the futures market does not contribute significantly to the price discovery process in the crude oil market. However, Schwarz and Szakmary (1994) argue that Quan's model is misspecified and that oil futures market lead spot market in price discovery.

The evidence of futures market has relatively evident advantages over spot market in prices has broadly found in the research of the price discovery literature. It suggests that futures markets are the forerunner in price discovery and provide valuable information about spot price movements. The findings in early study of Finnerty and Park (1987) on Major Market Index (MMI) suggests that futures markets provide price discovery. They find that the changes of stock index futures price are correlated with the changes of stock index price. Chan (1992) reveals that the futures price leads the spot index to a greater extent when stock prices move together under market-wide movements, suggesting that the futures market is the main source of market-wide information. These findings support the hypothesis that futures markets dominate discovery of future equilibrium price. The investors and speculators would benefit from efficient futures market to make optimal decision on their investment portfolios and avoid potential risk.

On the other hand, spot prices exert relatively strong effects on futures prices has been found in studies by, such as, Stefan and Whaley (1990), Chan (1992), and Shyy et al. (1996) on stock index markets; and Quan (1992), Moosa (1996), and Silvapulle and Moosa (1999) on crude oil markets.

Moreover, little work has been done to explore price discovery across spatially different futures markets for a commodity. Among this limited amount of research, Eun and Shim (1989) find the dominance of US equity markets in information dissemination to rest of the world. Liu and An (2009) investigate price discovery among spot markets of copper and soybean in China, and contracts of the same assets from three different futures markets in China, US and UK. As there is no overlapping trading hours between Chinese markets and markets of US and UK, they investigate the price interaction based on non-synchronous trading information. The research on international linkages across markets with no overlapping trading hours has primarily focused on the financial asset markets (King and Wadhwani, 1990, Susmel and Engle, 1994, Booth et al., 1998, Fung et al., 2001).

Additionally, there is research on price discovery function among three categories of markets. Chu et al. (1999) examine three S&P 500 index markets: the spot index, the futures index, and S&P Depositary Receipts (SPDRs); So and Tse (2004) explore Hang Seng Index, Hang Seng Index futures, and the tracker fund; Covrig et al. (2004) investigate Nikkei 225 spot index traded on Tokyo Stock Exchange (TSE), Nikkei 225 futures contracts traded simultaneously on Osaka Securities Exchange (OSE) and the Singapore Exchange (SGX). All these studies confirm that futures markets lead spot markets in price discovery.

3.3 Overview of Literature on Testing Market Efficiency Hypothesis and Unbiased Futures Hypothesis

Due to the highly liquid and low transaction costs of futures markets, futures markets are expected to be efficient and play a dominate role in price discovery. In the efficient futures markets, futures prices provide accurate forecasting of subsequent spot prices. Evidence consistent with futures market efficiency in recently papers covers commodities futures markets (Beck, 1994), interest rate (Jumah et al., 1999), and equity markets (Pizzi et al., 1998, Chu et al., 1999, Ackert and Racine, 1999). Canarella and Pollard (1986) confirm the unbiasedness hypothesis for copper, lead, tin and zinc using both overlapping and non-overlapping data during 1975-1983. MacDonald and Taylor (1988) suggest the copper and lead futures contracts in London Metal Exchange are efficient during 1976-1987. Serletis and Banack (1990) test market efficiency on crude oil, gasoline and heating oil by using cointegration analysis, and their findings support the market efficiency hypothesis. Results of studies by Crowder and Hamid (1993) and Sadorsky (2000) using cointegration analysis suggest that crude oil futures in New York Mercantile Exchange is efficient, and crude futures prices are unbiased predictors of future spot prices. By utilizing Johansen cointegration technique, Nieto et al. (1998) find Spanish futures index (Ibex 35) can be characterized as an efficient market to its underlying stock index for the period examined.

Ghosh (1993) suggests cointegration between futures and spot prices is not consistent with market efficiency. Many studies have rejected efficiency of distant past futures prices as predictors of spot prices at the maturity. Goss (1981) tests the unbiased futures prices hypothesis of four non-ferrous metals from London Metal Exchange during 1971-1978. Tested hypothesis for lead and tin is rejected, but it cannot be rejected in the case of copper and zinc. In Goss (1985) later study of Efficient Market Hypothesis on the same metals of the London Metal Exchange for the period of 1966-1984, he rejects the hypothesis for copper and zinc.

MacDonald and Taylor (1988) suggest that futures contracts for tin and zinc traded on the London Metal Exchange are inefficient. Sephton and Cochrane (1990, 1991) rejects unbiasedness hypothesis for six metals traded in London Metal Exchange during 1976-1985 and concludes London Metal Exchange is not an efficient market. Kenourgios and Samitas

(2004) analyze the joint hypothesis of market efficiency and unbiased futures price hypotheses for the copper futures contract on the London Metal Exchange. They show that London Metal Exchange is inefficient and does not provide accurate estimate of future copper spot prices. Kumar and Sunil (2004) investigate futures markets in agricultural commodities in India, and finds those commodities are not efficient and futures prices are not unbiased predictor of the future spot prices.

3.4 Overview of Literature on Causal Relationship

Kawaller *et al.* (1987) introduce the principle that both spot and futures prices are affected by their past history of price movements, as well as by current market information. They suggest that the lead-lag relationship of markets may change by new coming information. The major question is which market reacts first.

A large number of studies attempt to identify lead-lag relations between futures and spot markets for a range of assets. Empirical research concentrates mainly on S&P 500 in the US indexes (Kawaller et al., 1987, Stoll and Whaley, 1990, Herbst and Maberly, 1992, Chang, 1992, Dwyer et al., 1996, Monoyios and Sarno, 2002). It also covers stock market worldwide, such as stock markets in Japan (Tse, 1995), and stock markets in Hong Kong (Tang et al., 1992). The discussion has concentrated on whether the centralized equities market leads the futures market or vice versa.

More recent research has investigated equities markets in various countries including the SPI in Australia (Twite, 1991, Hodgson et al., 1993, Hodgson et al., 1996), the CAC in France (Shyy et al., 1996), FOX (Finnish Options Index) in Finland (Puttonen, 1993), Hang Sang index futures in Hong Kong (Tang et al., 1992), Nikkei Stock Average in Japan (Tse, 1995) and the FT-SE 100 in UK (Abhyankar, 1995, 1996, Taylor et al., 2000), and the Ibex in Spain (Caballero and Novales, 1995, Climent and Pardo, 1996, Nieto et al., 1998).

Besides, price leadership in the commodity futures markets has been the focus in a number of studies, such as, Schwarz and Szakmary (1994), Moosa and Alloughani (1994), Gulen (1998), Girma and Paulson (1999) and Silvapulle and Moosa (1999) on gas oil and crude oil. However, evidence regard to price leadership is conflicted.

The Error Correction Model has been widely used to explore the lead-lag relation between cointegrated futures and spot markets across various studies. It explains the short- and long-run price discovery dynamics in order to predict further prices movements and provides market participants and policy makers with valuable information regarding their investment decisions and for economic policy (Cho and Ogwang, 2006).

Tse (1995) finds futures price of the Nikkei Stock Average (NSA) affect the short-term adjustment in its spot index using the Error Correction Model. In the studies by Wahab and Lashgari (1993), Fleming et al. (1996) and Pizzi et al. (1998) on the temporal causal linkage between Index and stock Index futures prices for both the S&P 500 and the FTSE 100 Index, the estimation results by cointegration and error correction models suggest futures prices lead stock prices (Ryoo and Smith, 2004). Ghosh (1993) also find adjustments in S&P 500 index depend to a great extent on its futures price changes through the Error Correction Model. Xia and Cheng (2006) discover a long-run equilibrium relationship and lead-lag relationship among the Dalian Commodity Exchange in China, The Chicago Board of Trade futures market and China's domestic spot market of soybean using both of the vector autoregressive and vector error correction models.

A significant number of empirical studies investigate the dynamic relationships between spot and futures price utilizing the vector auto regression model (VAR) or cointegration method proposed by Engle and Granger (1987) and Johansen (1988a). Various results on the nature of the lead–lag relationships are given studies across different commodity and financial markets in different countries. These conflicting results have been produced by empirical research indicate that, (a) futures prices tend to lead spot prices, (b) spot prices tend to influence futures prices, and (c) a bi-directional feedback relationship exists between spot and futures prices. Kavussanos and Nomikos (2003) argue that the causality directions depend on the market under investigation, and Silvapulle and Moosa (1999) indicated that the lead-lag relationship may vary significantly over different time periods.

3.4.1 Empirical Findings of Futures Market Leading Spot Market

There are a large number of studies have revealed that futures prices contain useful information on changes of spot prices. It indicates that futures prices can be accurate predictors of future spot prices. It may suggest that futures markets benefit informed traders, hedgers and speculators with risks management, and policy makers in markets should pay attention on the effects of the futures markets.

The evidence of futures prices unidirectional lead spot prices has been discovered widely across studies on various stock index markets worldwide. Schwarz and Laatsch (1991) examine the Major Market Index at New York Stock Exchange. Pradhan and Bhat (2009) reveal the causal relationship of Nifty index markets by means of the error correction model (ECM). Both Caballero and Novales (1995) and Climent and Pardo (1996) look at Spanish stock index markets, followed by Nieto et al. (1998) using Johansen cointegration and Granger causality techniques. Tse (1995) examines futures price leadership in Nikkei stock market through Granger causality analysis and Error Correction Models. So and Tse (2004) study Hong Kong stock exchange. Gee et al. (2005) prove Financial Futures Exchange of Kuala Lumpur Options and Financial Futures Exchange in Malaysia and its Malaysian spot markets are integrated, and futures prices cause spot prices. Also the stock index markets in France, Germany and the UK are investigated in the studies by Abhyankar (1998) and Antoniou et al. (2001).

Likewise, futures prices cause spot prices has been revealed in commodities markets. Silvapulee and Moosa (1999) and Karande (2006) find the evidence in the futures prices of crude oil and castor seed. Asche and Guttormsen (2002) discover a long-run relationship and leading role of futures prices in futures and spot markets for oil utilising Engle-Granger method and Error Correction Model for their research. Figuerola-Ferretti and Gilbert (2005b) and Fontenbery and Zapata (1997) support the argument that futures markets cause the spot markets regard to aluminium markets and cheddar cheese markets respectively.

Interesting research brings by Praveen and Sudhakara (2006) attempting to compare price discovery between stock (Nifty futures traded on National Stock Exchange) and the commodity futures markets (gold futures on Multi Commodity of India). The result empirically presents that the one month Nifty futures contract does not have any influence on the Nifty spot price, but influenced by Nifty futures itself. The casual relationship test in the commodity market showed that gold futures price influences the spot gold price, but not vice versa. Thus, it implies that information is first disseminated in the futures market and then later reflected in the spot market.

3.4.2 Empirical Results of Spot Market Leading Futures Market

Even though empirical research generally discovers that futures markets lead spot markets, there are few studies suggesting the opposite hypothesis that spot markets may lead futures markets. This conclusion has been found in the studies of Green and Joujon (2000), which show the evidence that the French CAC-40 spot index leads its futures contract; Moosa (1996) suggests that change in the spot price would trigger action from markets participants leading to a subsequent change in futures prices. Subrahmanyam (1991), Chan (1992) and Abhyankar (1995) argue that informed traders are optimal to trade in spot markets rather than in futures markets.

3.4.3 Empirical Results of Bi-Directional Feedback Relationship between Spot and Futures Prices

Kawaller *et al.* (1987) postulate a bi-directional feedback relationship between spot and futures prices when both futures and spot prices are affected by their past history, current and past futures prices and other market information. In the studies on index markets by Chan (1991), Tang *et al.* (1992), Abhyankar (1998), Turkington and Walsh (1999), Zou and Pinfold (2001) and Raju and Karande (2003), their results suggest the existence of bi-directional causality between futures and spot prices and both markets react simultaneously to new information. Tse (1999) also reveals feedback relationship between DJIA futures and spot markets, but he suggests price discovery first takes place in the futures market. A balanced feedback relationship has been found in the study by Silvapulle and Moosa (1999) on crude oil market, and by Hua (2005) on copper, aluminium, and rubber. These studies confirm that spot markets can play an essential role for price discovery as futures markets.

Some studies have discovered that futures markets lead is strong than the spot markets lead, such as, studies by Harris (1989), Stoll and Whaley (1990), Chan (1990), Chan *et al.* (1991), Wahab and Lashgari (1993) and Pizzi *et al.* (1998) on stock index futures markets of Major

Market Index (MMI), FTSE 100 and S&P 500; by Hung and Zhang (1995) on interest rate futures; and Min and Najand (1999) by Korean stock index futures.

3.5 Overview of Research on Spatial Markets

The concepts of dominant and satellite markets relationship is initially introduced by Garbade and Silber (1979) in their study on temporal price relationship of an identical assets trading in the New York Stock Exchange and regional stock exchanges. They find that dominant market prices of New York Stock Exchange influence the satellite market prices.

Further research on the spatial price relationships of spot index markets has been explored. Eun and Shim (1989) used Vector Autoregression model and the Johansen cointegration test to examine the relationships among nine biggest stock markets worldwide from New York, Tokyo, London, Toronto, Frankfurt, Zurich, Sydney, Hong Kong, and Paris. Empirically, a high degree of interaction has been found among all nine markets, and the US stock market is suggested being the leading market. Cheung and Mak (1992) demonstrate that US stock market is leader of Asian stock market, which includes Japan, Hong Kong, Singapore, Philippines, Malaysia, and Australia; meanwhile, they also find Japan does not obviously lead any of the tested Asian stock markets by utilizing error correction model and Granger causality to test those stock markets' short and long-term dynamic relationships.

By using the cointegration theory, Arshanapalli and Doukas (1993) observe strong dynamic links between international stock markets before the 1987 financial crisis; besides, this interdependence among all tested stock markets has increased substantially after the 1987 financial crisis except Japan. Furthermore, there is little linkage between the performance of the Japanese stock market and those of the US, France, UK, and Germany during the 1987 crisis. Cointegration test is also adopted by Ghosh (1999) to identify long-term relationships between stock markets of Hong Kong, India, Malaysia, and South Korea, and another long-term relationship between Japan, India, Philippines, and Singapore. The US and Japanese stock markets have influence over tested Asian developing stock markets, apart from Taiwan and Thailand's.

By using the Vector Autoregression model, Gerrits and Yuce (1999) suggest US stock market has impact over three stock markets of European nation countries, namely Netherlands, US and Germany; and all these markets are interdependent in both of short- and long-term. Roope and Zurbruegg (2002) find that Singapore futures market is more efficient than Taiwan futures exchange for Taiwan Index futures listed in both markets.

Likewise, some studies have examined the dominant and satellite derivatives markets as well. Booth et al. (1998) discover that wheat futures price in the Chicago Board of Trade cointegrates and leads wheat futures price in the Canadian Winnipeg Commodities Exchange. Tian and Shen (2005) analyzed the causality relationship between the copper futures price of Shanghai Futures Exchange and that of London Metal Exchange, proving the increasing influences of copper futures price of Shanghai Futures Exchange on copper futures price in world market.

In the studies by Hua and Chen (2004), and Gao and Liu (2007), feedback relationships between the Shanghai Futures Exchange and the London Metal Exchange for copper and aluminium futures markets have been observed. Meanwhile, soybean futures contracts in Dalian Commodity Exchange and the Chicago Board of Trade have also been found cointegrated. They conclude that information transmits from overseas futures markets to the Chinese markets.

Through Johansen's cointegration test, error correction model, Granger causality test and impulse response analyses, Hua and Chen (2007) reveal cointegration relationships exist between futures prices in China's Shanghai Futures Exchange and London Metal Exchange for copper as well as aluminium contracts. They also discover soybean futures prices from China's Dalian Commodity Exchange and Chicago Board of Trade are cointegrated, but not for the soybean futures prices from China's Zhengzhou Commodity Exchange and Chicago Board of Trade. In their further analysis, futures price of London Metal Exchange has been found being a greater impact over Shanghai Futures Exchange for copper and aluminium contracts, and futures price of Chicago Board of Trade being a greater impact over Dalian Commodity Exchange for soybean futures. Meanwhile, the Chinese futures markets have bidirectional relationship with London Metal Exchange and Chicago Board of Trade futures markets. Ge *et al.* (2008) the cotton prices of futures contracts trading on New York Board of

Trade and China's Zhengzhou Commodity Exchange are cointegrated and two futures prices have a bidirectional causal relationship.

3.6 Overview of Literature on Precious Metals

Xu and Fung (2005) summarize that existing studies on precious metal futures markets mainly addressed on three research interests: (1) the distribution properties of the futures prices; (2) the effect of business cycles and macroeconomic news releases on the futures price of precious metals; and (3) the price relationship between the spot market and futures market (see, Chow, 2001). Figuerola-Ferretti and Gonzalo (2009) state that a significant number of research for precious metals has focused on the relationship between silver and gold prices, such as, by Garbade and Silber (1983), Wahab (1995), Adrangi and Chatrath (2000).

For gold, silver, and platinum traded in New York mercantile exchange, Figuerola-Ferretti and Gonzalo (2008) empirically demonstrate that the futures price is the "dominant" price in the most liquid precious metals futures markets, namely, gold and silver markets. Platinum, unlike non-ferrous metals, its spot and futures prices contribute to price discovery, suggesting that spot markets is more important for platinum than for other commodities in price discovery.

Lucey (2011) states that works have been undertaken on various aspects of the operation and efficiency addressed on gold markets. There is significant empirical evidence has been provide by a range of academic studies done by researchers across decades, such as, Solt and Swanson (1981), Diba and Grossman (1984), Ma and Sorensen (1988), Aggarwal and Soenen (1988), Lucey and Tully (2006b), Aggarwal and Lucey (2007) and Tully and Lucey (2007) and Lucey (2010). Their findings suggest that the gold markets are inefficient, and imply possible exploitable anomalous behaviours. From reviewing a number of works by researchers, such as, Baker and Van-Tassel (1985), Tandon and Urich (1987), Ding *et al.* (1993), Byers and Peel (2001), Matsushita *et al.* (2006), Tully and Lucey (2007) and Khalifa (2011), Miao *et al.* (2011), Lucey (2011) finds that shocks to the gold price take a very long time to dissipate.

Chapter 4

Developed Hypotheses and Methodology

The purpose of this research is to investigate the relationship between price movements, efficiency of price discovery and causal relationship between financial market prices and the prices of their underlying assets addressed on world precious metal markets. Price discovery is characterized by long-run and short-term price discovery in this study. Based on existing literature and established price discovery theories, a series of research hypotheses developed for reaching the purpose are presented in this chapter. Followed by each hypothesis, model frameworks of actual models applied to examine hypotheses are demonstrated. This chapter is finished with the description of data adopted for this research.

In general, long-run equilibrium relationship is discovered by using the cointegration test, the long-run price discovery role and short-term price dynamics is estimated by using the Vector Error Correction Model (VECM henceforth) or Granger causality test. The existences of long-run equilibrium relationships and short-term lead-lag dynamics between two markets can provide possible arbitrage opportunity for investors and speculators.

Due to non-stationary data could cause spurious regression and therefore bias the study, non-stationary behaviour in each series is necessary to check by testing for unit roots (non-stationary) before processing these series. Of the numerous unit root tests, the augmented Dickey-Fuller (1979) unit root test and the Phillips-Perron (Phillips and Perron, 1988) nonparametric tests, abbreviated as ADF and PP, are the two standard procedures applied on examining the stationarity properties of each variable using in this study. If the unit root hypothesis of non-stationary is not rejected to the data in level, but rejected to the data in first differences, namely integrated of order one, then further estimations is possible to carry out.

A stable long-run relationship between financial market price and spot market price has been proved by a number of researchers addressed on different commodities by using cointegration theory, such as, Lai and Lai (1991), Mckenzie and Holt (1998), Kellard *et al.* (1999) and Yang *et al.* (2001); and Haigh (2000). Thus, the EG's (Engle and Granger, 1987) and

Johansen's (1991) cointegration tests are utilized to examine the existence of a common behaviour of non-stationary price series in this study. If the null hypothesis that two price series are not cointegrated is rejected, both price series cannot wander arbitrarily far away from each other (He, 1999). In the short term, these price series possibly deviate from the equilibrium position, but they keep up the long-run equilibrium relation (Feng et al., 2007). If they are cointegrated, VECM can be used to determine the short-term deviation from the long-run equilibrium; if they are not cointegrated, the Granger causality test can be employed to navigate direction of causation (Brahmasrene and Jiranyakul, 2007).

However, if only cointegration has been examined without further investigation of the long-run and short-term dynamics in the relationship between spot and futures prices, or between spot price and index, then the conclusion would have been incorrectly drawn that futures market or index market was efficient during examined periods (Kenourgios and Samitas, 2004). Therefore, among cointegrated time series, the hypotheses of market efficiency and price discovery imply a more efficient financial market (due to lower transaction costs) and the financial market being the main source of market-wide information, and the long-run dynamics hypothesis of the prices of precious metals futures contacts and indexes of precious metals are considered as an unbiased forecast of the future precious metals spot prices are tested. Moreover, certain types of Granger-causal relationships may exist and resulting in a lead-lag relationship between spot and financial markets in the short-term (He, 1999, Hutcheson, 2003). Short-term price discovery is demonstrated in the lead-lag relationship among these markets. Although cointegration relationship indicates a causal relationship, it does not necessarily distinguish the direction of causality among variables (Long and Wang, 2009).

Futures price is theoretically considered to lead spot price in both long and short-term when causality relationship between price series exists. Sets of VECMs depending on the stationary and cointegrated trend among tested time series are estimated in this research to determine causality relationship in both the long-run and short-term that whether futures or index market is efficient, whether futures price or index provides unbiased estimates of future spot price, and whether futures price or index has prediction power over spot price, then leads spot price.

The reasons and the process of building a VECM are fully explained in this chapter. The advantage of VECM in evaluating price discovery is that this model takes into account the lag terms in the technical equation that invites the short-term adjustment towards the long-run (Mahalik et al., 2009). Two versions of VECMs developed by Engle and Granger and Johansen are introduced in this research, depending on the postulated cointegration equation, to analyze the equilibrium price adjustments and determine what kinds of feedback exist between futures and spot markets, and between index and spot markets.

4.1 Pre-test for Stationarity

In time series models, the presence of unit root causes a violation of the assumptions of classical linear regressions. A unit root means that the observed time series is not stationary. When traditional regression analysis regarding non-stationary time series, apparently significant relationships may obtained from unrelated variables, which may yield a spurious relationship and incorrect statistical inferences therefore bias the study (Yang et al., 2005, Prusty and Nagar, 2008, Chen et al., 2009). Hence, to avoid a spurious relationship, it is necessary to perform the unit root test on variables to check whether the data is stationary or not.

Time series theories start by considering the generating mechanism, which should be able to generate all the statistical properties of the series, or at least the conditional mean, variance and temporal autocorrelations, like linear properties of the series conditional upon past data (Prusty and Nagar, 2008). For instance, a time series Y_t that is a function of past values and some random error:

$$Y_t = \rho Y_{t-1} + \varepsilon_t \tag{4.1}$$

The ρ term dictates how strongly the present value of Y is dependent on the prior value of Y while ε_t is an independent and identically distributed (i.i.d.) random variable. If $|\rho| = 1$, that is if the model has a unit root, then the model becomes

$$Y_t = Y_{t-1} + \varepsilon_t \tag{4.2}$$

which is known as a random walk. In this case, Y_t is integrated time series, and the series thus has a permanent memory such that past shocks to the series cumulate, which implies present value can be good forecast of future value (De Boef and Keele, 2004). Therefore, the null hypothesis of a non-stationary time series (a unit root) is obtained, if $|\rho|$ = 1. The existence of unit root can be obtained from transformed model via subtracting from both sides of Y_{t-1}

$$Y_t - Y_{t-1} = \Delta Y_t = (\rho - 1)Y_{t-1} + \varepsilon_t \qquad (4.3)$$

$$\Delta Y_t = \beta Y_{t-1} + \varepsilon_t \qquad (4.4)$$

where denoting $\beta = \rho - 1$;

and to test the significance of parameters of the new model. Testing for unit root means test of nullity of $|\rho|$ = 1, equivalents to testing $\beta = 0$. Rejection of the null if $\beta < 0$, implies 1< ρ <1. If there is an explanatory variable X_t that is also integrated and causally related to Y_t then these two series are cointegrated.

Non-stationary behaviour is typical in most economic and financial time series, the data however, needs to be transformed by using log transformation, and/or differencing (stochastic stationary) or detrending (trend stationary), in order to obtain stationarity (Buhr et al., 2008, Maniatis, 2009). If all the series are integrated, alternatively non-stationary, then the important issue is to what degree they are integrated (Buhr et al., 2008). If the transformed series is stationary, called integrated of zero, denoting $I(0)$, when the linear properties exist and has a finite variance, which means that series is time invariant, and also has a finite (auto)covariance (Hye et al., 2009). Or original series will be called integrated of order one, denoted $I(1)$, if series needs to be differenced once to achieve these properties. More generally, if a series needs differencing d times to become $I(0)$, original series is called integrated of order d, denoted $I(\mathrm{d})$ (Prusty and Nagar, 2008, Vogelvang, 2005).

Both cointegration tests and VECM are employed to assess hypotheses of long-run and short-term price relationships in this study. The essential precondition under these approaches is all the series should be integrated of the same order, namely stationary after first differencing.

Therefore, as suggested by most of researchers, such as Buhr (2008), Prusty and Nagar (2008), Husein (2009), and Maniatis (2009), the first step in the analysis is to test for the existence of unit root in each series to ensure the consistency of all the time series data used (against the stationary alternative) and pre-test each series to determine its order of integration is to apply the unit root tests.

The unit root tests were conducted for determining stationarity. It is conventional to test the null hypothesis that there is a unit root in the stochastic process. Dickey (1976), Fuller (1976), and Dickey and Fuller (1979) generate three different regression equations to test the unit root hypothesis. The first equation is the transformed regression model

$$\Delta Y_t = \beta Y_{t-1} + \varepsilon_t \tag{4.5}$$

The second adds an intercept or drift term

$$\Delta Y_t = \alpha_0 + \beta Y_{t-1} + \varepsilon_t \tag{4.6}$$

The third includes both a drift and a linear time trend

$$\Delta Y_t = \alpha_0 + \beta Y_{t-1} + \alpha_2 t + \varepsilon_t \tag{4.7}$$

Under the null hypothesis $\beta = 0$, the $\{Y_t\}$ sequence contains a unit root, and the first equation is a pure random walk model. The Dickey-Fuller (1979) tests (DF tests) involve estimating one or more of equation 4.5, equation 4.6 and equation 4.7 using ordinary least squares (OLS) in order to obtain the estimated value β and the associated standard error. Comparing the resulting *t*-statistic with the appreciate value reported in the DF tables to determine whether to accept or reject the null hypothesis $\beta = 0$. It is important to choose the correct number of lags in conducting DF tests. According to Enders (2010), including too few lags in the model, β and its standard error will not be well estimated, hence, the actual error process cannot be captured appropriately; too many lags reduces the power of the test to reject the null of a unit root.

Dickey and Fuller (1981) extended the DF tests to an autoregressive process of known order containing not more than one unit root. The procedure, called 'augmented' Dickey–Fuller (ADF henceforth) tests, consists of adding to the models 4.5, 4.6 and 4.7 lagged changes in the dependent variable to capture autocorrelated omitted variables which would otherwise, by default, appear in the error term.

4.1.1 Augmented Dickey-Fuller (ADF) Unit Root Tests

ADF tests are the simplest unit root tests that are valid in the presence of serial correlation of unknown from are modified versions of the DF tests. ADF tests were proposed originally by Dickey and Fuller (1979) valid only under the assumption that the error terms in the test regressions are serially uncorrelated. ADF tests assume that the number of unit roots (if any) in each of the variables and that the error term is a Gaussian white noise, the test statistics reported here are subject to the *t*-test distribution (Dickey and Fuller, 1979).

The same as DF tests, the unit root hypothesis of ADF test corresponds to $\beta \geq 1$ in the model and the statistics are based upon the usual ordinary least squares estimator of β in each model. The null hypothesis is that there is a unit root in Y_t, or H_0: $\beta = 0$, against the alternative H_1: $\beta < 0$. The distribution of augmented DF tests rely on the innovation process (ε_t) being white noise.

The test statistics can be based on ordinary least squares to determine a suitable specified regression equation for a time series Y_t for the augmented DF test for each series. Therefore to perform an augmented DF test on a AR(p) model the following regression should be estimated (Wang 2009):

$$\Delta Y_t = a_0 + \beta_1 Y_{t-1} + \sum_{t=1}^{n} \beta_t \Delta Y_{t-i} + \varepsilon_t \qquad (4.8)$$

t= 1, 2, . . . ,

with the number of lags being determined by a model selection procedure (such as AIC), or have alternatively assumed a fixed number of lags in practice by many researchers. An ADF test may indicate a unit root for some lag lengths (Enders 2010). Since the results of the unit root test can be sensitive to the lag length selected, this study evaluates optimal lagged length p with the multivariate generalizations of the Akaike Information Criteria (AIC).

$$\text{AIC} = T\ln(sum\ of\ squared\ residuals) + 2n \qquad (4.9)$$

where n = number of parameters estimated

T = number of usable observations

This method uses lagged length to evaluate the sample, minimizing the function and finding the residual sum of square minimization.

However, the DF test and ADF test suffer a number of problems. It might not be known whether an intercept and/or time trend belongs in model 4.7. Prior data exploration suggests that there might be a trend in the price series; if they are covariance stationary, they might be stationary around a deterministic trend. Since all price series appear to have trend in this study, a trend assumption should be include in the unit root test, but the problem is it can never be sure about including appropriate deterministic regressors in the test. The DF test considers only a single unit root. However, a ρth order autoregression has ρ characteristic root; if there are $d \leq \rho$ unit root, the series needs to be differenced d times to achieve stationarity (Enders 2010). Perron (1988) has suggested that ADF test may falsely conclude the presence of a unit root in a time series subject to a structural break (Husein, 2009).

Therefore, an alternative approach for checking the presence of unit root is suggested by Phillips-Perron (1988) can be regarded as a robustness test compared to the ADF test. It uses a method designed to overcome the problem that the error term is serially correlated, without including a lagged difference dependant, as in the ADF tests. It estimates the standard DF test, and modification is made so that the serial correlation does not affect the asymptotic distribution of the test statistics. Mainly, the ADF and Phillips-Perron tests differ in how they treat serial correlation in the test regressions. ADF test uses a parametric autoregressive structure to capture serial correlation; while, the alternative Phillips and Perron (1988) test (PP test) uses non-parametric corrections based on estimates of the long-run variance.

Phillips-Perron (1988) test is called non-parametric, because no parametric specification of the error process is involved, and it controls for possible correlation in the first differences of the time-series using a non-parametric correction, and 9allows for the presence of a non-zero mean and a deterministic time trend (Davidson and MacKinnon, 1993, Husein, 2009) .

Instead of choosing between either one of these test methods, researchers, like Enders (2010), Li (2001) and Wilkinson (1999) consider a safe choice is to use both types of unit roots tests, since they reinforce each other and added confidence to the results. Both of ADF and PP unit root tests for time series are thus performed to determine the order of integration of each variable and evaluated their properties in this study.

4.1.2 Phillips-Perron (PP) Unit Root Tests

Phillips-Perron (1988) test is based on the ordinary least squares for a suitable, specified regression equation for a time series Y_t for each series:

$$\Delta Y_t = a_1 + \beta_1 Y_{t-1} + \varepsilon_t \qquad (4.10)$$

where ε_t, is white noise. The PP test is the t-value associated with the estimated coefficient of β_1. The series is stationary if β_1 is negative and significant (Hye et al., 2009).

The null hypothesis of ADF and PP tests is all the time series contain a unit root. Note that the null hypothesis in each test is a unit root process, against the alternative hypothesis of a stationary process (Deng, 2006). The null should *not* be rejected if absolute value of the test statistics is smaller than the absolute value of the corresponding critical value in certain degree significance; otherwise, reject it (Yang and Leatham, 1999, Yang et al., 2001). This decision rule is applicable to both unit root tests presented in this study.

If $I(0)$ is not stationary based on a certain degree significant test, namely 1%, 5%, or 10%, then all of time series run first difference, if the results appear all of data reject unit root null hypothesis to accept alternative hypothesis no matter which kinds of ways and testing based on certain degree significant test (Chen et al., 2009). It means data are stationary after run first difference $I(1)$ based on certain degree significant test (Maniatis, 2009). If they are not stationary in level, but stationary in first differences, they may or may not be cointegrated (Brahmasrene and Jiranyakul, 2007).

Both the tests explained above examined the null of a unit root against the alternative of stationarity. One test which does otherwise, it has the null of stationarity. It is the test of Kwiatkowski–Phillips–Schmidt–Shin (1992) (KPSS henceforth) tests. In literature KPSS has often been used to complement ADF and PP tests and confirm their results. Even though Maddala and Kim (1998) find in their survey that KPSS test is very sensitive to the lag length used in the estimations, and it also has the same poor power and size properties as the traditional ADF and PP tests. KPSS test is the only popularly used test in which the null of stationarity is tested against a nonstationary alternative. Therefore, ADF and PP tests are employed in this study, because these tests are popular and well applied in majority of research and also their nulls are appropriate to the hypotheses of this research.

4.2 Hypothesis 1 (H1): Existence of Long-Run Cointegration between Pairwise Markets

The price discovery function implies the presence of an equilibrium relation binding the two prices together (Zhong et al., 2004). If there is a common factor driving the two sets of prices, any deviation from the efficient price (equilibrium) occurs due to new information flow in the markets, should cause prices in one or both markets to adjust to correct the disparity back to the equilibrium level (Mahalik et al., 2009). A cointegration relationship thus implies that two integrated series never diverge apart from each other in the long run, which they maintain an equilibrium, although they may diverge substantially from equilibrium in the short term, driven by different dynamic processes (Davidson and MacKinnon, 1993, Enders, 2010). Therefore, in order to reveal how prices in separate markets respond to the pricing information and causal link between them, the first hypothesis in this study is to look for whether the long-run cointegration relationship exists between prices.

If two series are integrated of different orders, they cannot be cointegrated. Lack of cointegration implies no long-run equilibrium among variables, so that they can wander arbitrarily far from each other (Enders, 2010). It would be surprising if two price series drifted apart from one another over time as that would present opportunities for arbitrage (De Boef and Keele, 2004). Theoretically, arbitrage activities should keep prices in futures markets from diverging beyond what is entailed by differential transaction costs (and other such factors) (Davidson and MacKinnon, 1993).

Once price series are integrated in an identical order, whether these series demonstrate cointegrative phenomena can be determined by employing Engle and Granger's (EG's henceforth) and Johansen's cointegration methods, that are introduced in the following sections, have been used by many previous studies on spatial price relationship (Acikalin et al., 2008, Yang and Leatham, 1999). Both EG's (1987) cointegration tests and Johansen's bivariate cointegration analysis (Johansen, 1991, 1995) are employed in this study, because the Johansen (1988) procedure provides more efficient estimates of the cointegrating relationship than the EG (1987) estimator (Gonzalo 1994). Also, Johansen (1988) test are shown to be fairly robust to presence normality (Cheung and Lai 1993) and heteroscedasticity disturbances (Lee and Tse, 1996).

4.2.1 Engle-Granger's Cointegration Tests

If all the price series are integrated of order one, $I(1)$, the Engle-Granger residual based cointegration tests are to determine if long-run equilibrium relationship exists between futures and spot prices, and between index and spot price. One of the most popular tests for (a single) cointegration has been suggested by Engle and Granger (1987). This method for checking cointegration is firstly to obtain values of the deviations from the long-run equilibrium relationship, and secondly seeks to determine whether these residuals of the equilibrium relationship are stationary, so called a residual-based cointegration test. Cointegration can thus be seen as the existence of a long-run relationship between series and economic theory leads to expect that cointegration should exist.

The ordinary least squares estimate of two series, f_t and s_t, can be demonstrated as below,

$$f_t = \beta_0 + \beta_1 s_t + e_t, \ t = 1, \dots, T, \qquad (4.11)$$

where f_t = futures price or index, and s_t = spot price at time t; β_0 and β_1 are parameters to be estimated. f_t and s_t have to be stationary, as the typical ordinary least squares regression will yield spurious results or will not be meaningful, if variables are not stationary (Gujarati 2003). In subsequent exposition the ordinary least squares residuals may refer to e_t denotes by

$$e_t = f_t - \beta_0 - \beta_1 s_t \qquad (4.12)$$

This observation of EG's tests for cointegration, where e_t is tested for stationarity by performing unit root tests. If s_t and f_t are integrated of order one, $I(1)$, and the residuals e_t are stationary, $I(0)$, then the null hypothesis (unit root) is rejected and it can be concluded that these two series are cointegrated of order 1, denote $CI(1, 1)$.

In relation to this study, the null hypothesis of no cointegration between two variables $\mathrm{f_t}$ and $\mathrm{s_t}$ —futures and spot prices, or index and spot price implies that the residuals are not stationary. Both ADF and PP unit root tests are performed to on these residuals to determine their order of integration. The null can be rejected at the 1% level when calculated statistics (t-ratio) are greater than the critical values at the 1% level, or can be rejected at the 5% level when calculated statistics (t-ratio) are greater than the critical values at the 5% level. The critical values depend on sample size and the number of variables used in analysis.

Engle and Granger's (1987) approach for cointegration is simple and popular for its certain agreeable attributes. However, it suffers from certain drawbacks that discourage its use (Enders, 2010). EG's method is a two-step estimator in which the stationary test is based on the regression residuals from the first step. Any errors introduced from first-step regression residual estimation will carry into the second-step estimation of cointegration (Du and Hansz, 2009).

Moreover, all the problems that afflict the unit root tests also afflict the residual-based cointegration tests. The cointegration tests are often severely lacking in power especially because of the imprecision or uncertainty of estimating β in the first step. Thus, failure to reject the null of no-cointegration is common in application, which may provide only weak evidence that two or more variables are not cointegrated.

According to Engle and Granger (1987), two cointegrated non-stationary time series implies a bounded linear combination of the two variables. However, Dickey, Jansen and Thornton (1991) argue that the EG's two-step cointegration approach is sensitive to the choice of dependent variables; therefore, the results of the test may not be consistent (He, 1999). Therefore, a robust cointegration approach based on the well-established likelihood ratio principle is demonstrated next.

4.2.2 Johansen's Cointegration Tests

Johansen (1995, 1991) introduced using the Maximum Likelihood (ML) method (hereafter called the Johansen's cointegration test), enabling the researchers to identify the maximum number of cointegrating vectors existing between a set of variables. Johansen's cointegration test thus can be used for two purposes: (i) Determining the maximum number of cointegration vectors for the variables; and (ii) Obtaining maximum likelihood estimates of the cointegrating vector and the adjustment parameters.

Johansen's bivariate cointegration test examines the restrictions imposed by cointegration on the unrestricted vector auto-regressive (VAR) model involving the series that allows for possible interactions in the determination of price series. Consider a VAR of order p.

$$f_t = \alpha_1 f_{t-1} + \cdots + \alpha_p f_{t-p} + \beta s_t + e_t, \qquad (4.13)$$

where f_t is a k-vector of non-stationary I(1) series, s_t is a d-vector of deterministic series, and e_t is a vector of innovations. The VAR can be written into

$$\Delta f_t = \pi f_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta f_{t-1} + \beta s_t + e_t, \qquad (4.14)$$

where $\pi = \sum_i \alpha_{i-1}$, $i = 1, \dots, p$

$\Gamma_i = -\sum_{j=r+1} \alpha_i$

Granger's representation theorem asserts that if the coefficient matrix π has reduced rank $\mathrm{r} < \mathrm{n}$, then there exists (r x n) matrices α and β where r is the rank of π, $\pi = \alpha\beta$. r is the number of cointegrating relations (the cointegrating rank) and each column of β is the cointegrating vector. In general, if price series f_t has *n* non-stationary components, then there may be a maximum of *n -1* linearly independent cointegrating vectors that is called the cointegrating rank of f_t (Buhr et al., 2008, Enders, 2010). The elements of α are known as the adjustment parameters in the VECM. Johansen's method is to estimate the π -matrix in an unrestricted form, and then test whether the restrictions can be rejected implied by the reduced rank of π.

Johansen's cointegration test is based around an examination of the π matrix, where π can be interpreted as a long-run coefficient matrix. The test is based on maximum likelihood estimation and produces two test statistics, namely trace statistics (λ_{trace}) and maximum eigenvalue (λ_{Max}) statistics in trace test and maximum eigenvalue test to determine the number of cointegrating vectors. The likelihood ratio test based on maximal eigenvalue of the stochastic matrix and the test based on trace of the stochastic matrix, thus the test for cointegration between the variables is calculated by looking at the rank of the π matrix via its eigenvalues and trace statistics. The null hypothesis of Johansen's cointegration test is no cointegrating relationship between two variables, denotes $\mathrm{r} = 0$, is tested against the alternative that one cointegrating vector exists between these two variables, denotes $\mathrm{r} = 1$.

The number of cointergration vectors is represented by the rank of the coefficient matrix Γ. The likelihood ratio test for the hypothesis that there are at most *r* cointegration vectors is called the Trace Test statistic, whether the number of cointegrating vectors is zero and one:

$$Trace\ Test = \lambda_{trace}(r) = -T\sum_{i=r+1}^{p} \ln\left(1 - \widetilde{\lambda_i}\right), \qquad (4.15)$$

where T is the sample size and $\widetilde{\lambda_{r+1}}, \dots, \tilde{\lambda}p$ are the $p - r$ smallest squared canonical correlations.

Another restricted maximum likelihood ratio is referred to as the Maximal Eigenvalue Test statistic whether a single cointegrating equation is sufficient or if two are required:

$$Maximal\ Eigenvalue = \lambda_{Maximal\ Eigenvalue}(r, r+1) = -T \ln(1 - \widetilde{\lambda_{r+1}}), \qquad (4.16)$$

where $\widetilde{\lambda_1^*}, \dots, \widetilde{\lambda_r^*}$ are the r largest squared canonical correlations. The maximal eigenvalue test produces clearer cut results.

The maximum eigenvalue statistic λ_{Max} tests the null hypothesis of r cointegration vectors, against the alternative of *r+1* cointegration vectors; while the alternative hypothesis in the trace statistic λ_{trace} test is that there exist more than r cointegration vectors (Buhr et al., 2008). Johansen and Juselius (1990) provide the critical values of these statistics.

The standard approach to the Johansen maximum likelihood procedure is to first calculate the Trace and Maximum Eigenvalue statistics, then compare these to the appropriate critical values. Null hypothesis can be rejected at certain significance level, when the computed statistics greater than critical values. The null hypothesis is r = 0 (no cointegrating vector) of both bivariate Trace and Max-Eigenvalue tests can be rejected even at a 5 % significance level with a linear trend, if the calculated test statistics are greater than the critical values. Rejection of the hypothesis of zero cointegrating vectors indicates 1 cointegrating vector at the 0.05 level. Critical values at 5% significance level are taken from Johansen and Juselius (1990) for the number of cointegrating vectors. Rejection of null hypothesis implies futures and spot prices, or index and spot price are $I(1)$, with linear combinations being I(0), so the two price series are $CI(1,1)$[8].

The rank of Π may be tested using the λ_{trace} and λ_{Max}. If rank (Π) = 1, then there is single cointegrating vector and Π can be factored as $\Pi = \alpha\beta'$, where α and β' are 2 1 vectors. Using this factorisation β' represents the vector of cointegrating parameters and α is the vector of error correction coefficients measuring the adjusted speed of convergence to the long-run steady state (Pradhan and Bhat, 2009).

When price series f_t and s_t are $CI(1, 1)$, with cointegrating vector $[1, -\beta]$, and the deviations from the long-run path are $I(0)$, then a model in first differences incorporating an error

[8] A cointegrating vector indicates that there is one linear combination for which the variance is bounded, that is, a stable long-run relationship between these variables.

correction mechanism can be developed (Lutz et al., 1995). Restrictions on the cointegrating vector(s) can be tested using x^2 statistics. Be aware of the role of the deterministic repressors in a cointegration framework (Enders, 2010). These issues are of fundamental importance to market efficiency because it is a necessary condition for the futures price to be priced efficiently. They can be tested by comparing the numbers of cointegrating vectors in cointegration analysis.

The Johansen's Maximum Likelihood approach has a number of advantages over the EG's two-stage approach to cointegration. Restrictions can be applied to the cointegrating vectors in Johansen's approach, which is not possible with the EG's approach. It can also be used for 'Granger Causality' testing, where the lags in the error correction model can be jointly tested for significance, thereby determining any short-term causality from the explanatory variables to the dependent variable. Moreover, Johansen's approach is possible to identify more than one cointegrating vector, but it does not impact on this research, as price series are tested in pairs.

4.3 Prediction Hypothesis

Price discovery may occur in both spot markets and financial (futures or index) markets. The former aims to discover equilibrium spot prices while the latter aims to find equilibrium financial prices. The essence of price discovery function of futures markets hinges on whether new information is reflected first in futures price or spot price (Hoffman, 1931). Theoretically when two markets for the same asset are faced with the same information arriving simultaneously, the two markets should react at the same time in a similar fashion (Bose, 2007). However, some markets react before others resulting some markets then lead the others (Hentze and Seiler, 2000, Chung et al., 2007).

Due to financial markets, such as futures markets and index markets search more for information than spot markets to find an equilibrium price, financial markets are expected to increase the information content of markets, thus greatly improve the price discovery function. The general consensus found in the price discovery literature was that the financial markets tend to lead the spot markets due to relatively lower transaction costs of the financial markets. Fleming, Ostdiek, and Whaley (1996) found that the market with lowest overall trading costs would react fastest to new information. Booth, Lee, and Tse (1996) also suggested that higher transaction costs may reduce market information pricing efficiency. Just as the futures markets generally provide price discovery for an underlying asset, it is to expect the index markets to expedite discovery for equilibrium. As with the futures markets, the index markets have relatively low trading costs. When such a lead-lag relation appears, the leading market is viewed as contributing a price discovery function for that instrument (Chung et al., 2007).

As an extension at price discovery hypothesis, prediction hypothesis asserts that financial market price discovers and establishes a competitive reference price for an asset, which is used to derive the subsequent spot price (Silvapulle and Moosa, 1999). As the centre of issues on the price discovery dynamics of the futures and index and spot markets, the prediction hypothesis is in relation to the forecasting ability of futures prices of precious metals and also their index, and contends that prices in the futures and index markets are useful predictors of subsequent spot prices in long-run and short-term. If the futures prices can explain the changes in the spot prices with a specified time lag, the futures prices possibly contain additional information beyond what has already embedded in the spot prices. Hence, futures prices are a predictor to spot prices. On the other hand, if the spot prices do not show similar predictive power over the futures, it can definitely say that futures prices are useful in predicting the spot.

According to Fama (1970), in an efficient market, prices should always fully reflect all available information. In such a market, the only price changes that can occur are those that result from new information. If futures market is efficient, futures prices should be the best and sufficient predictor of spot prices. The futures price and the expected spot price should differ only because ‘new’ information impinges on the market in the intervening time between the agreement of the futures contract and its maturity. If this is genuinely new information, it cannot be forecasted on the basis of current information. The future spot price, thus, will equal the futures price plus a random and unpredictable shock. A possible test of the forecasting ability of futures prices is therefore based on the regression. Therefore, the prediction hypotheses in relation to market efficiency and price discovery in this study are whether futures and index markets are efficient and observe efficient price rather than spot price.

Examining the persistence and direction of predictive power between variables is in the sense of Granger (1969) causality. Granger (1986) and Engle and Granger (1987) argue if cointegration exists, there is a long-run relationship between pairwised variables in question. Thus, Granger proposes that a more comprehensive test of causality must run in the sense of error correction modelling between these cointegrated variables, in order to describe price discovery dynamics in both short-term and long-run simultaneously. Vector Auto-regression model demonstrates how the past values of stationary variables influence each other, through incorporating past values of spot prices into the equation for futures prices and vice versa (Ramanathan, 1998, Zhong et al., 2004). However, Vector Auto-regression in the first difference can be mis-specified, due to the effect of a common trend. Vector Auto-regression should include residuals from the vectors, lagged at one period, by adding an Error Correction Model to the Vector Auto-regression that gives a dynamic Vector Error Correction mechanism (Johansen, 1988b, Buhr et al., 2008, Bekiros and Diks, 2008).

The use of cointegration analysis and VECM enables one to distinguish between short-term and long-run deviations from equilibrium indicative of price discovery and long-run deviations that account for efficiency and stability (Pizzi et al., 1998). The advantage of VECM relatives to the standard Granger causality is focusing on the short-term dynamic adjustment versus the long-run equilibrium relationship between the spot and futures prices, and VECM is fitted for spot price changes and futures price changes (Tse, 1995). It indicates that the predictability of these variables may be improved by incorporating information from the cointegrating relationship (Engle and Yoo, 1987). As suggested by the Granger Representation Theorem (Engle and Granger, 1987), when cointegration is found then there is long-run causality in at least one direction; either from futures to spot or vice versa; the short-term causality shows that previous day's futures price causes today's spot price or vice versa. Thus, an appropriate methodology for modelling the long-run and short-term dynamics of the system is a VECM when cointegration exists.

VECM restricts the long-run behaviour of variables to converge equilibrium through price adjustments, while allowing a wide range of short-term dynamics of past price within a linear system of simultaneous equations. The degree of cointegration is reflected in the specification of error correction term, which gradually corrects past deviations from long-run equilibrium through a series of partial short-term price adjustments (Chen et al., 2009). The error correction term is not a causal relationship measure. It represents the stable long-run relationship between two time series and its size can be affected by changes either in one variable or the other or both (He, 1999).

If cointegration has been observed by EG's cointegration approach, the EG's bivariate VECM uses the saved residuals from the estimation of the long-run equilibrium relationship, by adding the residuals from the ordinary least squares equilibrium regression into the standard VECM, presented as below:

$$\Delta s_t = a_s + a_1 \overbrace{e_{t-1}} + \sum \rho_{11}(i)\Delta s_{t-i} + \sum \rho_{12}(i)\Delta f_{t-i} + \varepsilon_{st} \qquad (4.17)$$

$$\Delta f_t = a_f + a_2 \overbrace{e_{t-1}} + \sum \rho_{21}(i)\Delta s_{t-i} + \sum \rho_{22}(i)\Delta f_{t-i} + \varepsilon_{ft} \qquad (4.18)$$

where Δs_t is a vector of log spot price, and Δf_t is a vector of log futures price or log index

$\overbrace{e_{t-1}}$ is the lagged residual in ordinary least squares regression,

a_1 and a_2 are the speed of adjustment parameters,

$\sum \rho_{11}(i)$, $\sum \rho_{12}(i)$, $\sum \rho_{21}(i)$, $\sum \rho_{22}(i)$ represent short-term effects,

a_s and a_f are parameters (intercept), and

ε_{st} and ε_{ft} are white-noise disturbances (which may be correlated with each other).

However, Hall (1986) opined that the error correction model in EG's cointegration techniques suffers from some drawbacks, particularly finite sample estimation bias. As mentioned in Urbain (1993), the critical values and small sample performance of many of the tests are unknown for a wide range of models, and informed inspection of the correlogram may still be an important tool. Pradhan and Bhat (2009) point out that evidence of cointegration among variables also rules out the possibility of the estimated relation being spurious.

Therefore, if the existence of long-run relationship between prices series is testified by Johansen's Maximum Likelihood approach, Johansen's (1988a) VECM can be employed to investigate the causal relationship between two prices series (He, 1999).

$$\Delta s_t = a_s + a_1[s_{t-1} - \beta_1 f_{t-1}] + \sum_{i=1}^{k} \rho_{11}\, \Delta s_{t-i} + \sum_{j=1}^{k} \rho_{12} \Delta f_{t-j} + u_t \qquad (4.19)$$

$$\Delta f_t = a_f + a_2[s_{t-1} - \beta_2 f_{t-1}] + \sum_{i=1}^{k} \rho_{21}\, \Delta s_{t-i} + \sum_{j=1}^{k} \rho_{22} \Delta f_{t-j} + e_t \qquad (4.20)$$

where β_1 and β_2 are the parameters of the cointegrating vector, β_1 is given by 1,

Δs_t is a vector of log spot price, and Δf_t is a vector of log futures price or log index

$[x_{t-1} - \beta_1 y_{t-1}]$ is the lagged residual from the cointegrating regression (random error terms),

a_1 and a_2 are the speed of adjustment parameters,

$\sum_{i=1} \rho_{11}(i)$, $\sum_{i=1} \rho_{12}(i)$, $\sum_{i=1} \rho_{21}(i)$, $\sum_{i=1} \rho_{22}(i)$ represent short-term effects, and

a_s and a_f are parameters (intercept), and

u_t and e_t are white-noise disturbances (which may be correlated with each other).

In order to gauge the existence of simultaneous price adjustment in the two markets, the first difference spot price (Δs_t) were used as the dependent variable in a regression were the independent variables f_t were represented by lead, contemporaneous and lag futures price or index, as in Equations 4.17 and 4.19. Equations 4.17 and 4.19 postulate the current Δs_t is a function of the previous periods lagged residual and lagged changes in values of Δf_t, as well as the lagged changes in values of Δs_t, and the degree to which the two series are outside of their equilibrium in the previous time period is represented by $a_1 \widehat{e_{t-1}}$ and $a_1[s_{t-1} - \beta_1 f_{t-1}]$ respectively in equations 4.17 and 4.19. Similarly, Equations 4.18 and 4.20 states the current Δf_t is related to the previous period's equilibrium error of the lagged changes in values of both Δs_t and Δf_t.

These two-variable Error Correction Models are bivariate Vector Auto-regressions in first differences augmented by the lagged error correction term, EC_{t-1} , $ec^s_{t-1} = a_1 \widehat{e_{t-1}}$ and $ec^f_{t-1} = a_2 \widehat{e_{t-1}}$ in EG's VECM of Equations 4.25 and 4.26, $ec^s_{t-1} = a_1[s_{t-1} - \beta_1 f_{t-1}]$ and $ec^f_{t-1} = a_2[s_{t-1} - \beta_2 f_{t-1}]$ in Johansen's VECM of Equations 4.19 and 4.20. Lagged error correction term can be thought of as an equilibrium error or disequilibrium term occurred in the previous period, it represents the dynamics of the long-run relation linking the two series and measures the differences between the two prices, so that disequilibria in any period are corrected in the next. If it is non-zero, the model is out of equilibrium and vice versa. The error correction term is comprised of two components, the speed of adjustment parameters a_1 and a_2 , and cointegrating vectors β_1 and β_2 are consisting of error correction and cointegrating vectors (error correcting mechanism in the system), imply lagged values suggest the short-term effects and the long-run effects.

In the two versions of VECM, their equations above describe the long-run as well as short-term dynamics of the equilibrium relationship between s_t (spot price) and f_t (futures price or index). Where Δs_t and Δf_t are the first difference price for the spot and futures prices (index) respectively. In the system of these equations, both prices series may be influenced by past and present values of each other. Thence, lead-lag relations between these price series can be tested.

4.3.1 Hypothesis 2 (H2): Unbiased Predictor Hypothesis

Long-run prediction is associated with the efficient market hypothesis (EMH) that includes two conditions: the first condition is corresponding to the theory of cointegration relation binding prices in two markets do not drift apart in the long run, which a given change in financial price can predict the persistent (long-lasting) change in spot price; the second condition requests that price changes in one market are fully matched in other markets.

The test for the second condition is also called a test of financial market efficiency and is closely associated with the price discovery role. The efficient market hypothesis and price discovery function of futures markets assume that financial markets efficiently process all relevant information to be reflected simultaneously into both spot and financial prices, and then spot and financial prices share a one-to-one long-run equilibrium. In this case, the financial prices are known as an unbiased predictor of the future spot price. Therefore, the second hypothesis in this study is called unbiased futures prices hypothesis that the financial price are an unbiased predictor of the future spot price. If the current financial prices are an unbiased predictor of future spot prices, it can provide direct evidence in favour of price discovery occurring primarily in the financial prices market, and market efficiency on financial prices market becomes the precondition and foundation of price discovery efficiency (Yang and Leatham, 1999, Hasan, 2005).

The unbiased futures prices hypothesis is one form of the EMH asserts that the one-period financial price of an asset should equal the expected value of the asset's spot price in the next period. The null hypothesis of EMH can be re-stated as the financial price is informationally efficient. The crucial question is whether financial price is an unbiased estimate of market expectations of future spot price. This question is of fundamental importance because it asks if the financial price is useful hedging instruments.

The unbiased predictor hypothesis immediately implies an equilibrium relationship between spot and financial prices, which may be captured by the long-run parameter, or called cointegrating vectors β existing in Johansen's VECM. The coefficient β reflects the long-term equilibrium effect of one price on the other that occurs over future time periods. A limitation of the EG's type of residual-based tests, is that no strong statistical inference can be drawn with respect to the cointegrating vectors β. One of the most interesting aspects of the Johansen procedure is that it allows testing restrictions imposed on parameters in the cointegrating vector β for Market Efficiency in a Vector Error Correction representation. Therefore the analysis can be extended to test whether two variables respond the same when shock (new information) coming. Thus, to be an unbiased predictor of future spot price, the movements of financial and spot prices must be proportional where the other necessary condition for futures efficiency market hypothesis is that $\{s_t\}$ and $\{f_t\}$ be cointegrated with $|\beta_1| = |\beta_2| = 1$ in Johansen's VECM equations.

Therefore, in Johansen's VECM estimations, the cointegrating coefficient β estimates the degrees of influence by new available information that logarithmic futures price or index can have on logarithmic spot price.

It formally conducts asymptotic chi-square tests on the cointegrating parameters. β_1 is normalized to be 1, so that one tests the restriction that the cointegrating parameters of the prices are equal but have opposite signs. The null hypothesis is the cointegrating vector is β = (1, −1). If the null cannot be rejected for any market pair at a reasonable significance level, it means under this condition the prices react equally in the long run. If $\beta_1 = 1$ cannot be reject, it may indicate that say, gold financial price is an unbiased estimate of the future gold spot price; on the other hand, if the hypothesis of $\beta_2 = -1$ can be reject, then it may conclude that the no-arbitrage condition is satisfied in gold market.

The market efficiency hypothesis requires that the change in spot price and in its associated futures price should be perfectly contemporaneously correlated and not cross-autocorrelated (Tse, 1995). However, in the short run, prices in markets can vary in a non-synchronous manner, due to the existence of transaction costs or some kind of price sluggishness. The major implication of the Fama's (1970)efficient hypothesis is that it is increasingly difficult for any single investor to outperform the overall market for an extended period of time (Nardella, 2007).

4.3.2 Short-term Prediction Hypothesis

The short-term prediction hypothesis contends that lagged futures price or index has significant predictive power for spot price over finite forecasting horizons. Short-term prediction implies that a given change in futures prices or indexes can predict temporary change in spot price. VECM is to judge this short-term predictive power of each market over the other by observing lead-lag relationship between them. The lead-lag relationship implied by the VECM suggests the predictability of the futures or spot price may be regarded as evidence against the efficient market hypothesis (Tse, 1995). The short-term dependencies among the prices can be identified through hypothesis testing on α and ρ in VECM, so called short-term parameters.

4.3.3 Hypothesis 3 (H3): Hypothesis of Price Discovery Role

The price discovery function of futures markets does not only mean that the futures market can finally forms a reasonable price by colleting different information, but also represents that the futures price has an important leading role in the future market price. Therefore, conditioned on the existence of a long-run relationship, ECM draws inference about Granger Causality.

The long-run effect occurs at a rate dictated by the value of a, who capture the short-term adjustment to the long-run relationships, can be conducted in a similar way to that used for hypothesis testing on β. This hypothesis will be supported if the lagged error-correction term (EC_{t-1}) can effectively predict current changes in spot prices (see, Zapata and Rambaldi, 1997, Yang et al., 2001). If the theoretical relationship between spot and futures prices holds the coefficient on the contemporaneous futures price should be different from zero while the other coefficients should not be different from zero (Hutcheson, 2003). It allows the researchers to draw inferences regarding the short-term adjustment processes of each price series. It also enables to test whether a particular market is weakly exogenous with regard to other markets (if those market prices are unresponsive to the deviation from long-run relationships) (Haigh et al., 2004).

The speed of adjustment parameters a measures the relative speed of adjustments in the single period response left hand side variable adjusts to the previous period's deviation from long-run equilibrium path. If two price series are both $I(1)$ and have a long-run equilibrium relationship, there must be some force which pulls the equilibrium error beck to zero (Engle and Granger, 1987). Where, the coefficients of error correction vector, $\alpha = [a_1\ a_2]$ interpreted as the mechanism speed of adjustment of financial and spot prices toward equilibrium in the period *t-n*, and if it is negative and statistically significance that confirms the long-run relationship and also show the speed of the long-run adjustment price driven by the error in previous period short-term disequilibrium adjusts itself to re-establish long-run equilibrium.

Information about price leadership is formally tested on the coefficients α. Examination of the speed of adjustment parameter provides insight into the adjustment process of two prices towards equilibrium. If the correction coefficient statistics is significant and in accord with error correction mechanism that assures common long-run moves (the long-run relationship) of two variables, two variables would repair the non-equilibrium state and the system strays away from the equilibrium state. The response of one variable to the deviations from common long-run changes in the other variable shows the speed of adjustment from short-term disequilibrium to long-run equilibrium (Hye and Siddiqui, 2010). In this case, if one price exists in equilibrium, a short-term divergence in linear relations in previous period will subsequently return to equilibrium. Thus, the movement of the price can be predicted under a VECM.

Under this price discovery hypothesis, deviations from the spot/futures markets or spot/index markets long-run equilibrium help predict subsequent movements in spot prices in next period. As Asche and Guttormsen (2002) and Yang et.al (2001) suggest, the price discovery hypothesis can be formulated as statistical tests with respect to the matrix $a = (a_1\ a_2)$. Examination of the speed of adjustment coefficients (α_1 and α_2) provides insight into the adjustment process of spot and futures/index prices towards equilibrium. This price discovery hypothesis posits that index/futures price impacts spot price changes through the long-run price equilibrium channel. In a bivariate VECM, at least one of the coefficients of a_s or a_f must be non-zero and statistically significant, implying that the prices of the two prices are responsive to last period's equilibrium error. If $a_s \neq 0$ and statistically significant, a change in basis will be at least partly corrected by a change in the spot price; while if $a_f \neq 0$ and statistically significant, a change in basis will be at least partly corrected by a change in the futures price/index. It should then be obvious that if $a_s = 0$, there are no changes in the spot price due to changes in basis and all corrections will have to made by changes to the futures price/index, and vice versa if $a_f = 0$. Hence, if $a_s = 0$ futures price/index will leads spot price, if $a_f = 0$ spot price will lead futures price/index. If $a_s \neq 0$ and $a_f \neq 0$, both futures and spot prices react and there is a bidirectional long run information flow between spot and futures prices, thus, there will be no price leadership in this system and it is particularly interesting in further testing the possibility that futures/index markets are at least as important as spot markets in generating price information in the long run, that is, $|a_s| \leq |a_f|$. If $a_s = a_f = 0$, the long-run equilibrium relationship does not appear and the model is not one of error correction or cointegration.

This parameter determines how fast the series returns to the long-run equilibrium after disequilibrium occurred in the cointegrating relation. Serletis and Herbert (1999), Buhr (2008), Pradhan and Bhat (2009) state, the statistically significant coefficients α in Equations 4.17 and 4.19 measure the single period response Δs_t (change in spot price) to departures from equilibrium. A statistically significant small α indicates Δs_t adjusts only fractionally to correct the disequilibrium situation, so most of the adjustment is accomplished by Δf_t (change in futures price). A statistically significant small α in Equations 4.18 and 4.20 indicates the Δf_t (change in futures price) responds very little to correcting the disequilibrium situation, so most of the adjustment is accomplished by Δs_t (change in spot price). If absolute value of a_1 is greater than absolute value of a_2, it implies the greater the response of Δs_t to the previous period's deviation from long-run equilibrium than Δf_t does, and more information flows from Δs_t to Δf_t. At the opposite extreme, very small values of a_s imply that the spot price is relatively unresponsive to correcting the disequilibrium situation and hence it will reach the long-run equilibrium only relatively slowly. If the two error correction coefficients are similar in magnitude, their contribution to price discovery and their speed of adjustment from short run disequilibrium to long run equilibrium are also similar.

The lack of significance in futures price (f_t) equation indicates that spot price (s) in the current period *t* does not respond to disequilibrium in the previous period; in like manner, lack of significance in spot price equation indicates that futures price (f) in the current period *t* does not respond to disequilibrium in the previous period (Ryoo and Smith, 2004).

Hutcheson (2003), and Chaihetphon and Pavabutr (2010) state the sign of significant coefficient a implies a direct convergence to the long-run relationship. If coefficient of long-run equilibrium error correction term a is positive and significant, it means that an increase in the previous period *t - 1*'s equilibrium error leads to an increase in the current period spot price; by contrast, if a is negative and significant, it means that an increase in the previous period *t - 1*'s equilibrium error leads to an decrease in the current period spot price.

In response to a positive deviation from their equilibrium relationship at period *t−1*, when futures price is lower and spot price is higher than equilibrium at previous period *t – 1*—$S_{t-1} > F_{t-1}$, the spot price is expected to decrease in value and futures price is expected to increase at current period *t* to eliminate any disequilibrium. Therefore, both spot and futures prices adjust to eliminate any deviations (disequilibrium) from their long-run relationship. It implies that price adjusts to correct disequilibrium from last period $t - 1$, and re-establish long-run equilibrium in current period t. It says the price that makes adjustment to close the gap between it and the other price series plays the role of price discovery, in this case, both futures and spot contribute to price discovery. If the two prices adjust to eliminate any deviations from their long-run relationship, and, since the two error correction coefficients are similar in magnitude, their contribution to price discovery is also similar.

4.3.4 Hypothesis 4 (H4): Short-Term Causality Hypothesis

The lead-lag relationship illustrates how well the two markets are linked, and how fast one market reflects new information from the other (Floros and Vougas, 2007). As Antoniou and Garrett (1993) point out, lead-lag relationship exists if futures price reacts to economy-wide information. If new market information disseminates in, say, the futures market before the spot market, then the introduction of futures market increases the amount of information reflected in the spot price (Ryoo and Smith, 2004).

The degree to which one variable's fluctuation explains the behaviour of other variables is defined by Granger (1969) causality (Chen et al., 2009). Granger causality thus helps determine whether one variable is the cause, whether both variables demonstrate feedback, or whether there is simply no relationship between the variables. Therefore, a complete classification of the patterns of causality relationship has three dimensions in this study: whether the spot market causes the futures market; whether the futures market causes the spot market; and whether instantaneous causality exists (bi-directional feedback) exists (Harvey, 1990, Floros and Vougas, 2007).

The Error Correction Terms capture the long-run relationships, while individual coefficient of the lagged differenced term ρ in VECM equation represent short-term adjustments (effects/dynamics) of the left-hand-side variable to the previous period's change in price, and provide information about the feedback interaction and may be use to produce forecasts (Tse, 1995). In both VECMs, the short-term dynamics of the variables in the system are influenced by the deviation from equilibrium. Based on cointegration analysis, the short-term dynamics between two variables is measured by the coefficients on certain number the lagged difference terms as suggested by model selection criteria such as Schwarz information criterion, Akaike information criterion, or Hannan-Quinn information criterion, in unrestricted bivariate VECMs. The results imply whether change in yesterday's and previous day's futures price has significant influence on change in today's spot prices, contrarily whether past move of spot price create impact on current changes in futures price or index.

As lead and lag coefficients statistics ρ is significant, futures price and spot price, or index and spot price are affecting by price changes in the last periods. If f_t is the futures price or index at the time t and s_t it the underlying spot price at the time t. In Vector Error Correction regression, if the lag coefficients ρ_{t-k} are significant, the futures returns (prices) lead the spot returns (prices); if the lead coefficients ρ_{t+k} are significant, the spot returns (prices) lead the futures returns (prices). When both lead and lag coefficients are jointly significant, the process suggests a bi-directional causality (Hasan, 2005).

It has been stated, if Δf_t and Δs_t are cointegrated, then there must be Granger causality in at least one direction. In the Granger causality framework, given that a lead-lag relationship can be at least in only one direction, say from *s* to *f*, the only question that remains is whether such a relationship actually exists. Answering this question is to regress s_t on f_t and test the coefficient of s_t for 'significance'.

The short-term prediction hypothesis contends that lagged futures prices have significant predictive power for spot prices over finite forecasting horizons. This hypothesis is akin to the Granger-causality concept and can be tested in the VECM system. The lead and lag coefficients statistics ρ captures any immediate effect that s_t has on f_t, or f_t on s_t, defines as a contemporaneous effect or short-term dynamics to the changes of the process (Juselius, 1995).

If some of estimated coefficients statistics ρ of lagged financial price in spot price equation (Equations 17 and 4.19) are statistically significant, while the set of estimated coefficients statistics ρs in financial price equation (Equations 4.18 and 4.20) are statistically insignificant, then it implies that financial price tends to lead spot price under the unidirectional causality, in other words, previous period's equilibrium error of financial price leads the current period spot price and is consistent with the price discovery hypothesis.

In contrast, if some of estimated coefficient statistics ρ for financial price are statistically significant in financial price equation (Equations 4.18 or 4.20) while all the estimated coefficient statistics ρ in spot price equation (Equations 4.17 and 4.19) are statistically insignificant, then it implies that spot price tends to lead financial price under the unidirectional causality, or it can says that the previous period's equilibrium error of spot price causes the current period financial price.

If both of these events occur, there is feedback relationship between two price series. If all the coefficients of financial price and spot price are insignificant in each other's regressions, independence occurs.

4.3.5 Diagnostic Checks

However, high correlation between two set data creates spurious correlation. The problem of spurious correlation remains even if some dynamic structure is imposed on the model by taking *f* to depend on current and past values of *s* (Harvey, 1990).

ε_{st} and ε_{ft}, e_t and u_t are the error terms in EG's and Johansen's VECMs respectively which may be correlated, or exhibit autocorrelation. Additional lags should be added into the analysis until the residuals are independent. An estimate will be made regarding the VECM for each variable, where the lagged residuals from the equilibrium regression are included (Buhr et al., 2008).

To assess the adequacy of the VECM, Enders (2010) perform diagnostic tests to determine whether, or not, the residuals from the aforementioned estimations approximate white noise, and whether the Vector Error Correction estimated model is appropriate. If the residuals are serially correlated, lag lengths are to be short and need to be extended until they yield serially uncorrelated errors (Buhr et al., 2008).

In order to ensure that the residuals of Maximum Likelihood and Ordinary Least Squares estimations are not autocorrelated, the serial correlation Lagrange multiplier test is a test for autocorrelation in the errors in a regression model. It makes use of the residuals from the model being considered in a regression analysis, and a test statistic is derived from these. The Lagrange multiplier test statistic is asymptotically distributed as a χ^2 with p degrees of freedom. The null hypothesis of the Lagrange multiplier test is that there is no serial correlation up to lag order *p*. In this case there are up to twelve lags for the equations for the associated variables.

Lagrange multiplier gives the p-value for significance of the Lagrange multiplier test. A p-value of 0.1 means the statistic is significant at the 10% level, of 0.05 means significance at the 5% level. If a p-value is >0.1 then null hypothesis cannot be rejected. If the p-value is >0.3 or even greater then there is only very weak serial correlation in the residual.

4.3.6 Direction of Causality between Non-Cointegrated Price Series

The absence of cointegration could mean that an absence of a long-run relationship between financial and spot prices, the violation of the necessity condition for the simple efficiency and price discovery hypotheses, which also implies that the financial market price is not an unbiased predictor of the spot price at maturity. Therefore, if cointegration does not exist, Granger bivariate causality tests are employed to determine the direction of causation between variables.

As VECM estimate causality in both long run and short term respectively, Granger (1969) causality gives an overall causality between variables. Based on the premise that "the future cannot cause the present or the past", the validity of the test depends on the order of the Vector Autoregression model and on stationarity or non-stationarity (Geweke, 1984). In 1988, Granger extended his test to include the concept of cointegration. However, the standard Granger test is likely to provide invalid causal inferences when time series are cointegrated. This is due to the error correction terms are not included in the standard Granger (Hye et al., 2009).

The pair-wise Granger causality tests are used to examine whether the past value of on price series, say financial price f_t , will help to predict the value of another price series, spot price s_t, at present financial price f_t taking into account the past value of f_t, or vice versa, or both happened.

$$f_t = a_0 + \sum a_j f_{t-j} + \sum \beta_j s_{t-j} + \varepsilon_{f,t} \quad (4.21)$$

$$s_t = c_0 + \sum c_j s_{t-j} + \sum d_j f_{t-j} + \varepsilon_{s,t} \quad (4.22)$$

where $\varepsilon_{f,t}$ and $\varepsilon_{s,t}$ are mutually un-correlated white-noise series.

a_j is the parameter of the past value of f_t, which represents how much past value of f_t explains the current value of f_t,

and β_j is the parameter of the past value of s_t, which represents how much past value of s_t explains the current value of f_t. Similar meanings apply to c_j and d_j (Mucuk and Yilmaz, 2010).

4.4 Data Description

Empirical analyses will systematically examine the price discovery function between futures / index market and spot market in precious metals. Three precious metals with unique and essential economic and industrial characters are gold, silver and platinum. Most of the time gold trading is for the investment purpose, as majority of gold is stored by governments and banks to stabilize economy and avoid risk from economic fluctuations. In comparison, silver has a broader use in both investment and industry, and demand in platinum focuses on manufactures. As a result, the decisive factors of their spot price are different to each other. Hence, it is interesting to discover their price relationships among these metals. As we explained above, 4 main hypotheses have been set to examine price relationship of each metal and the price discovery functions of futures price / index markets in both long-run and short-term.

The markets tested in this research are not restricted from one region. They are major players from global precious metal markets. The development of globalisation and manufacture leads an increase in international trading and information linkage among international markets. The well developed futures exchanges with significant trading volume has become vane for price change in spot markets around the world. Precious metal markets participants can use efficient futures markets to lower the risk in trading and investment. Therefore, understanding of the price relationship in global precious metal market will benefit investors and traders in precious metals markets worldwide.

4.4.1 Gold Markets in Chapter 5

The gold daily spot prices from four main producers, manufacturers and traders are Perth Mint in Australia, Handy & Harman (H&H henceforth) in US, London Bullion Market Association (LBMA henceforth) in UK, and Mexico; daily settlement futures prices of the nearest unexpired 3 month gold contracts from three major world futures exchanges are Tokyo Commodity Exchange (TOCOM henceforth) in Japan, New York Mercantile Exchange (NYMEX henceforth) and Chicago Board of Trade (CBOT henceforth) in US, and gold indexes from well known investment indexes of Standard & Poor's (S&P's henceforth) and Merrill Lynch are also selected for this research. And all the price series used for the analysis are transformed into natural logarithmic values of their actual values and listed in the Table 4-01 as below.

Table 4-01

Definition of Price Series of Gold

Variable Series Name	Denoted in log levels	Data Source	Data Duration
Closing Futures Prices	FUS^{CBOT}	Chicago Board of Trade (CBOT)	06/10/2004 - 29/02/2008
Closing Futures Prices	FUS^{NYMEX}	New York Mercantile Exchange (NYMEX)	24/03/2000 - 29/02/2008
Closing Futures Prices	FJP^{TOCOM}	Tokyo Commodity Exchange (TOCOM)	24/03/2000 - 29/02/2008
Index	IML	Merrill Lynch	24/03/2000 - 29/02/2008
Index	ISP	Standard & Poor (S&P)	24/03/2000 - 29/02/2008
Mid of average daily Spot Prices	SAU	Perth Mint	24/03/2000 - 29/02/2008
Mexico Daily Spot Prices	SMX	Mexico	24/03/2000 - 29/02/2008
PM London Fixing Spot Prices	SUK	London Bullion Market Association (LBMA)	24/03/2000 - 29/02/2008
Noon-time Base Prices	SUS	Handy and Harman (H&H)	24/03/2000 - 29/02/2008

Data used in this research has different measurements, for example, indexes are in points, futures and spot prices are in different currencies per various units, like US Dollar per 100 troy ounces or Yan per kg, which may cause difficulty in comparing and interpreting changes of those price series, and prices with the same measurement would be plotted in tight cluster on the graph when plotting untransformed price series. Log transformation demonstrates change in the value of a series that is a percent of the value rather than an absolute value. After transforming into natural logarithms, the first differenced series can be interpreted as the growth rates of indexes, futures and spot prices, which price series would be easier to interpret changes and subsequent empirical analysis allows for examination of percentage changes, meanwhile, the points will be spread more uniformly in the graph plotted by using logarithmic transformed data, so that it improves interpretability and visualization. For these reasons, natural logs of the values of the price series are used in this analysis, rather than the original raw values.

All the gold price series in natural logarithm and natural logarithmic of price series in first difference are plotted in the graphs below. These graphs show all series of logarithmic levels and first differences of gold rise and fall closely together over time; hence it indicates they share a possible strong linear relationship. This is also can be evidenced by the high value, as the high correlation between two price series suggests that they are related. Moreover, both graphs show a trend assumption should be including in the unit root tests. Unit root tests in this study allow for intercept and trend as the deterministic components in estimateing regression.

Figure 4-01 Logarithmic Gold Futures Price in Tokyo Commodity Exchange

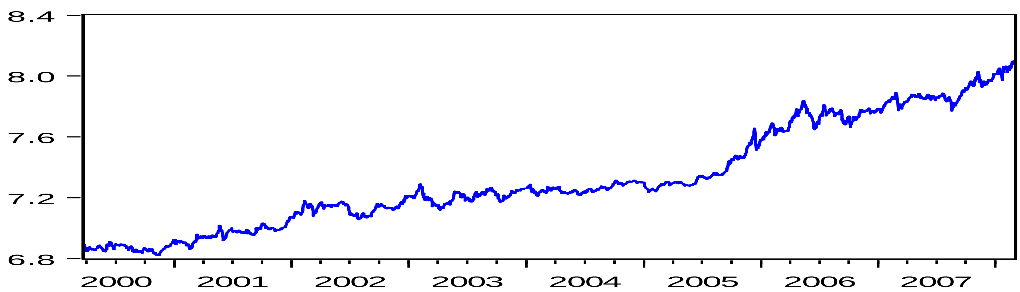


Figure 4-02 Logarithmic Gold Futures Price in Chicago Board of Trade

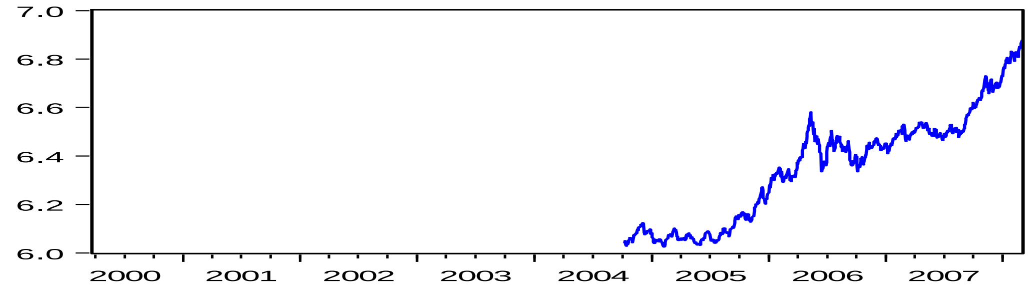


Figure 4-03 Logarithmic Gold Futures Price in New York Mercantile Exchange

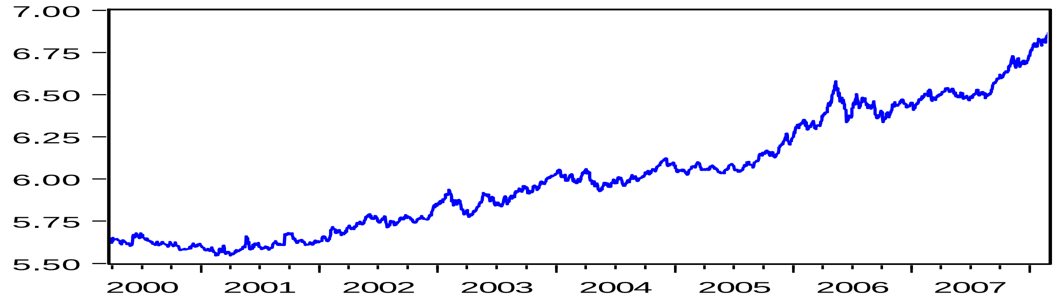


Figure 4-04 Logarithmic Gold Index in Merrill Lynch

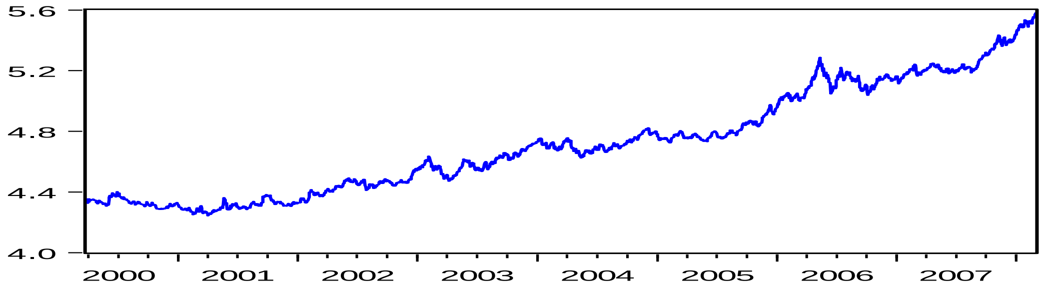


Figure 4-05 Logarithmic Gold Index in S&P

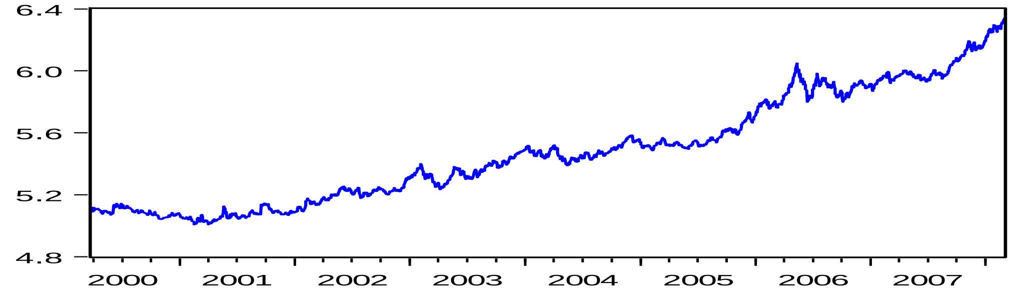


Figure 4-06 Logarithmic Gold Spot Price in Australia

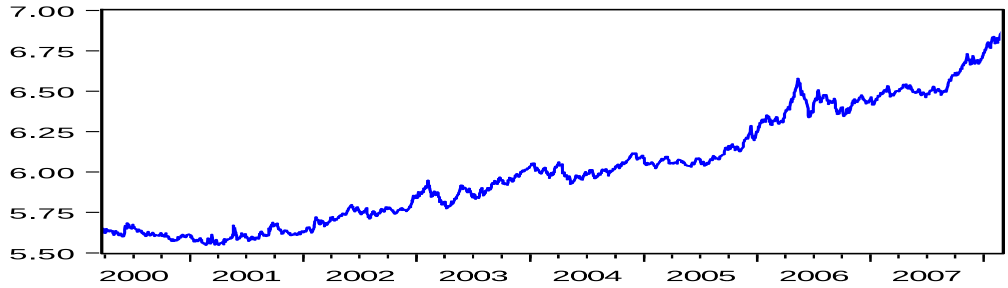


Figure 4-07 Logarithmic Gold Spot Price in Mexico

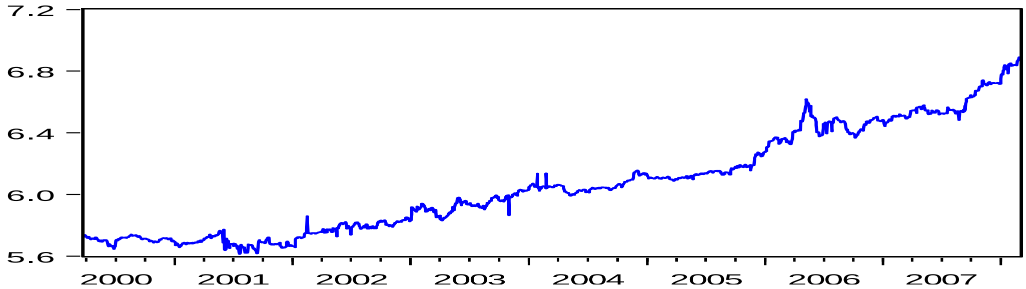


Figure 4-08 Logarithmic Gold Spot Price in UK

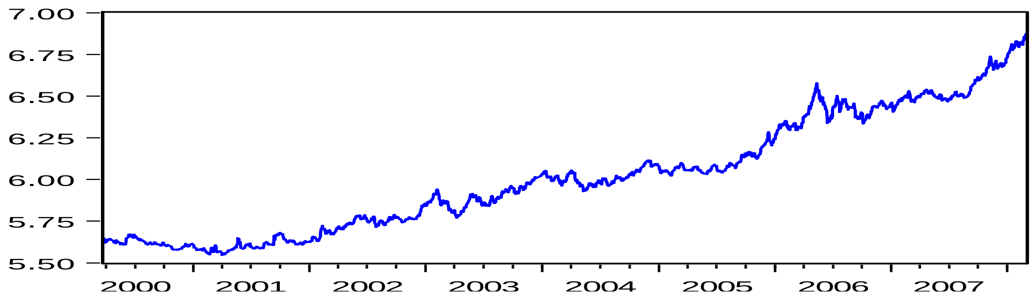


Figure 4-09 Logarithmic Gold Spot Price in US

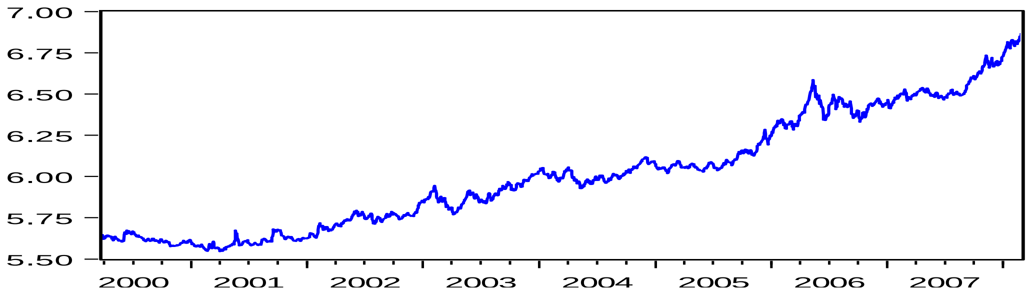


Figure 4-10 Logarithmic Gold Futures Price in Tokyo Commodity Exchange in First Different

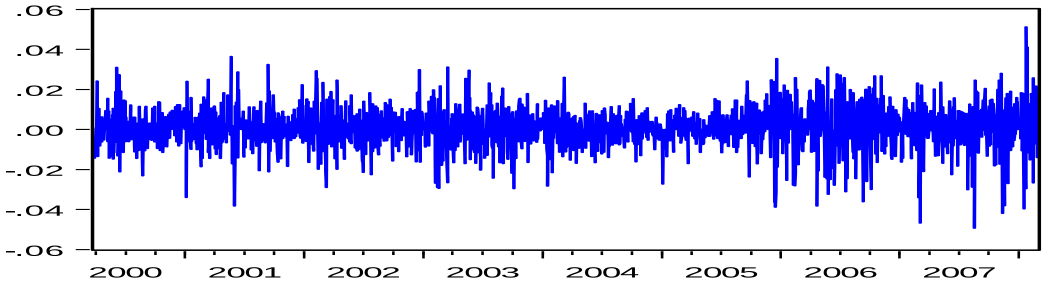


Figure 4-11 Logarithmic Gold Futures Price in Chicago Board of Trade in First Different

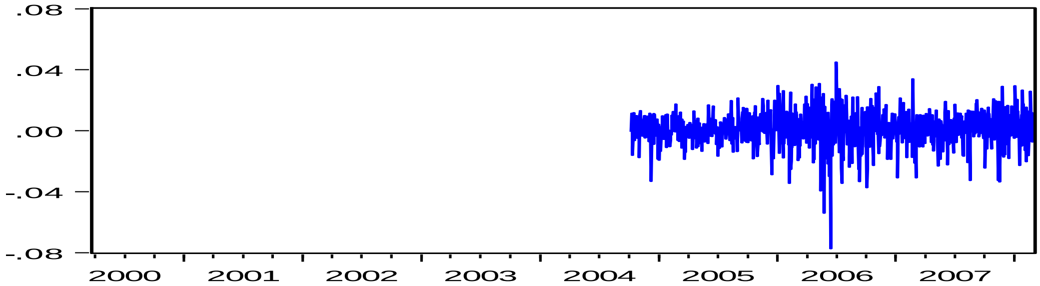


Figure 4-12 Logarithmic Gold Futures Price in New York Mercantile Exchange in First Different

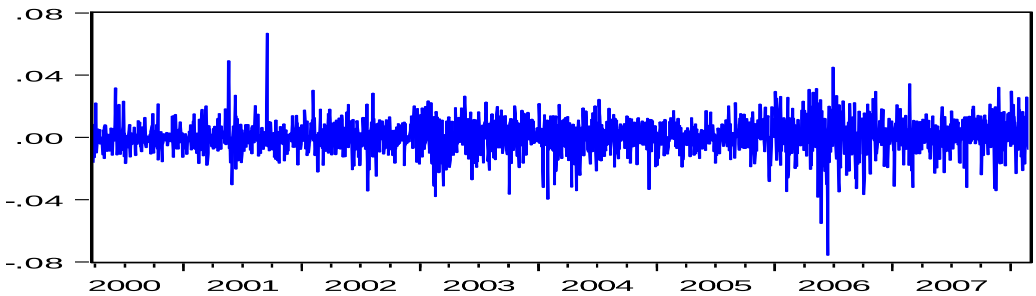


Figure 4-13 Logarithmic Gold Index in Merrill Lynch in First Different

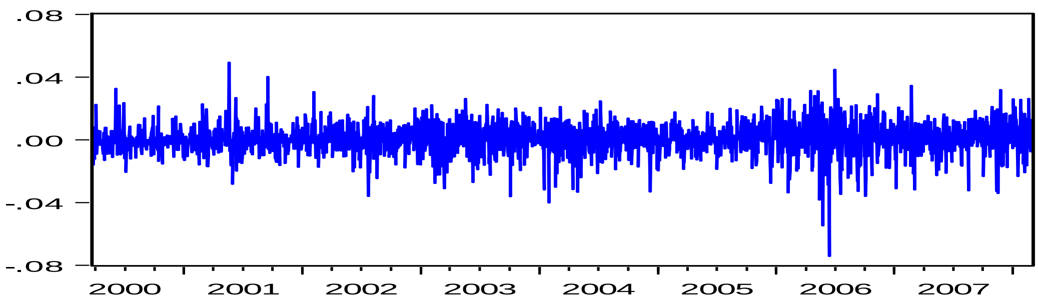


Figure 4-14 Logarithmic Gold Index in S&P in First Different

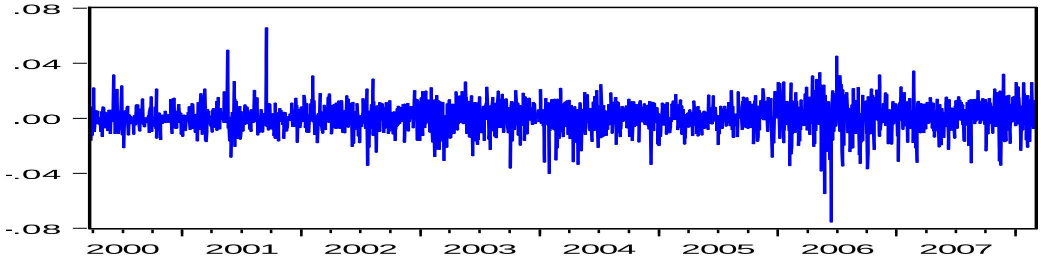


Figure 4-15 Logarithmic Gold Spot Price in Australia in First Different

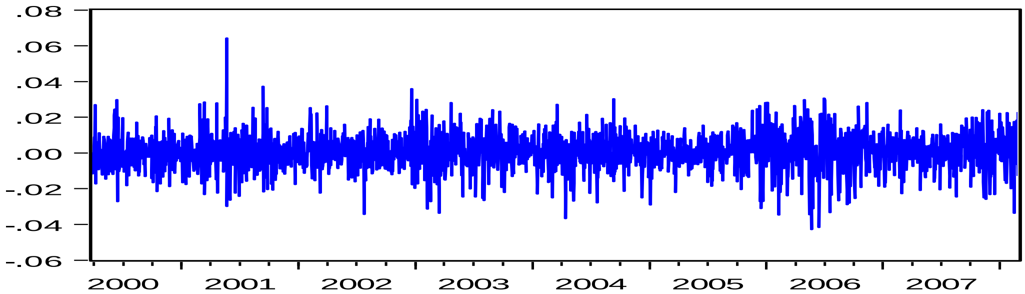


Figure 4-16 Logarithmic Gold Spot Price in Mexico in First Different

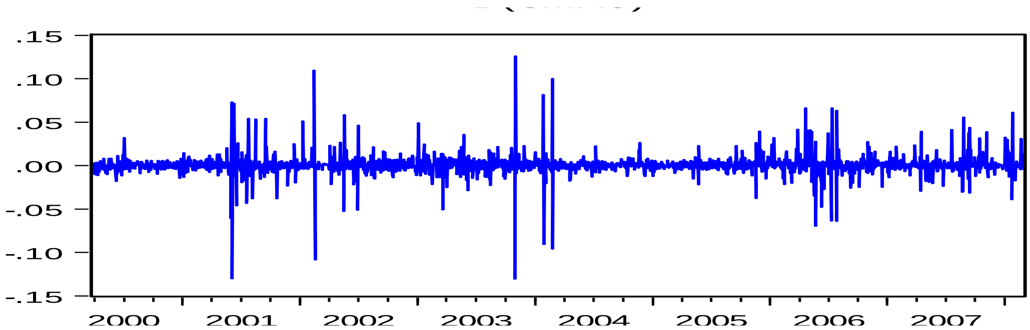


Figure 4-17 Logarithmic Gold Spot Price in UK in First Different

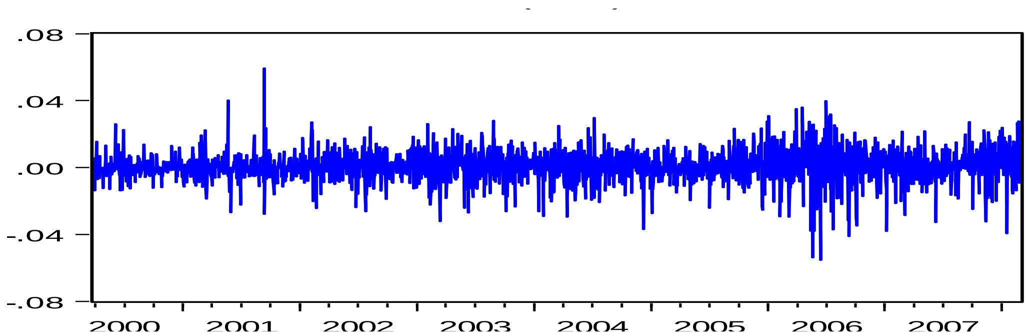
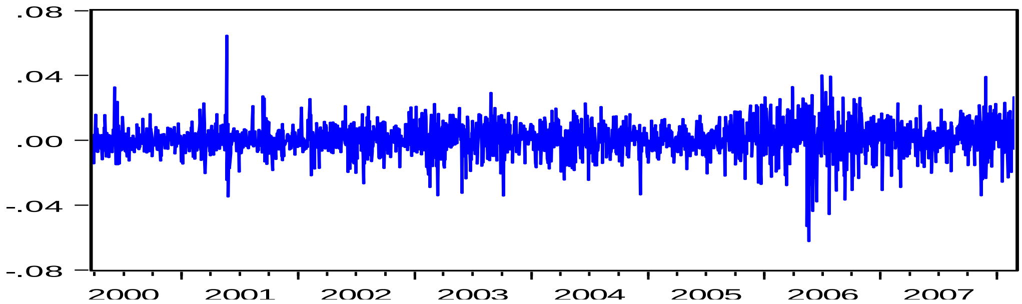


Figure 4-18 Logarithmic Gold Spot Price in US in First Different



The descriptive statistics of gold data in Table 4-02 and Table 4-04 include samples means, medians, maximums, minimums, standard deviations, skewness, kurtosis or degree of excess, sum of square deviations, observations, coefficient of covariation and the Jacque-Bera statistic and p-value of index, futures and spot prices of gold show clear similarity and appear to move closely are reported.

Kurtosis measures whether the data are peaked or flat, relative to a normal distribution. Skewness is a measure of symmetry, or more precisely, lack of symmetry. If the skewness coefficient equals to 0 and the kurtosis coefficient more than 3 for a normally distributed variable, this implies that the variance is due to infrequent extreme deviations as opposed to frequent modestly-sized deviations. If the skewness coefficient is negative and thus skew to the left; if the skewness coefficient is positive and thus skew to the right.

As a consequence, the Jarque–Bera (1980) test is an asymptotic test, which indicates significant departures from normality for the spot, index and futures returns series. It is a test of the joint hypothesis that skewness coefficient and the kurtosis coefficient are 0 and 3, respectively. On the other hand, the calculated Jarque-Bera statistic and corresponding *p*-value is used to test the null hypotheses that the daily distribution of price series is normally distributed. Each two price series are characterised by non-normality as evident from the high kurtosis and the high calculated Jacque-Bera statistic. All corresponding *p*-values are smaller than the 0.01 level of significance suggesting the null hypothesis is rejected.

Summary statistics and the Jarque–Bera test of normality of series — index, futures and spot prices in both levels and first differences of logarithmic gold price series are analyzed in this section and summarized (Summary Statistics for the Observations of gold) in Table 4-02 and Table 4-04, followed by Ordinary Covariance Analysis on all series of gold.

Table 4-02 summarized the statistics for all the observations regard to logarithmic price of gold. It shows that the mean of Merrill Lynch's gold index in levels is less than the mean of other series in levels, the mean of TOCOM gold futures price in levels is the highest, and the mean of the rest of gold price series in levels are almost similar. The standard deviation of CBOT futures price in levels is less than the standard deviation of other series in levels, and the rest of series in levels has almost similar standard deviation. The existence of a little positive skew and excessive leptokurtosis is consistent with the standard statistical features of price series. The Jarque-Bera statistics are statistically significant at the 5% level, indicating that all these log series are not normally distributed, which suggests that these log series are not stationary.

Table 4-02

Summary Statistics for the Observations of Log Gold Price Series in Levels

	FUS^{CBOT}	FUS^{NYMEX}	FJP^{TOCOM}	IML	ISP	SAU	SMXC	SUK	SUS
Mean	6.352710	6.017828	7.326701	4.721017	5.481558	6.017497	6.064991	6.016602	6.015943
Median	6.397013	5.987457	7.245655	4.685690	5.448288	5.986954	6.029242	5.987331	5.986703
Maximum	6.878532	6.879459	8.098947	5.583282	6.341505	6.870095	6.892063	6.878090	6.878841
Minimum	6.023932	5.544396	6.820016	4.243612	5.006560	5.546466	5.613092	5.545177	5.544982
Std. Dev.	0.225039	0.345900	0.339630	0.347423	0.346728	0.345988	0.328133	0.345735	0.345692
Skewness	0.116010	0.477924	0.527444	0.486748	0.484337	0.474484	0.540086	0.477103	0.476748
Kurtosis	2.041370	2.118275	2.133472	2.105347	2.110609	2.116197	2.162315	2.118366	2.117612
Jarque-Bera	35.99373*	145.9267*	160.8183*	150.8463*	149.2282*	145.1123*	161.0791*	145.6420*	145.6399*
Probability	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Sum	5641.207	12462.92	15173.60	9777.227	11352.31	12462.24	12548.47	12460.38	12459.02
Sum Sq. Dev.	44.91977	247.6690	238.7711	249.8552	248.8559	247.7953	222.6645	247.4329	247.3710
Observations	888	2071	2071	2071	2071	2071	2069	2071	2071

The Jarque-Bera statistic tests whether a series is normally distributed under the null hypothesis of normality.
* Indicate statistically significant at 5% level.

Ordinary Covariance Analysis on gold price variables in Tables 4-03 reports coefficient of correlation and observations. As expected, the futures and spot markets, or the index and spot markets are significantly positively correlated, and most of variables exhibit correlation higher than 0.99. Gold price series correlation coefficients between TOCOM futures and each tested spot prices is between 0.98 and 0.99, which means the correlation between TOCOM gold futures market and each gold spot markets is less than correlation between US gold futures markets and each tested gold spot markets, and less than correlation between each US gold index markets and each tested gold spot markets.

Table 4-03

Covariance Analysis of log Gold price series in levels					
Covariance Analysis: Ordinary					
Sample: 3/24/2000 2/29/2008					
Included observations: 2071					
Pairwise samples (pairwise missing deletion)					
Correlation					
Observations	FUS^{CBOT}	FUS^{NYMEX}	FJP^{TOCOM}	IML	ISP
SAU	0.999155	0.999688	0.984876	0.999600	0.999623
	888	2071	2071	2071	2071
SMX	0.978520	0.995237	0.995261	0.995233	0.995190
	888	2069	2069	2069	2069
SUK	0.999686	0.999866	0.984821	0.999791	0.999814
	888	2071	2071	2071	2071
SUS	0.999564	0.999827	0.984827	0.999748	0.999775
	888	2071	2071	2071	2071

Table 4-04 summarized the statistics for all the observations regard to logarithmic price of gold in first differenced. It shows the mean of gold series in first difference are almost similar. The standard deviation of Mexico spot series in first difference is highest, and the standard deviations of the rest series are almost similar. The skew of Mexico gold spot price in first difference is to the right, while the skew of the rest series in first difference are to the left. Since the kurtosis, or degree of excess with significant Jarque–Bera statistics, the distributional properties of the gold price series in first difference generally appear non-normal.

Table 4-04

Summary Statistics for the Observations of First Differenced Log Gold Price Series

	D (FUS^{CBOT})	D (FUS^{NYMEX})	D (FJP^{TOCOM})	D (IML)	D (ISP)	D (SAU)	*D (SMX)*	D (SUK)	D (SUS)
Mean	0.000945	0.000593	0.000579	0.000592	0.000589	0.000589	*0.000554*	0.000593	0.000593
Median	0.000523	0.000000	0.000000	0.000000	0.000000	0.000709	*0.000414*	0.000183	0.000157
Maximum	0.044904	0.066763	0.051190	0.049309	0.065754	0.064334	*0.594623*	0.059455	0.064710
Minimum	-0.077487	-0.075740	-0.049433	-0.074485	-0.075557	-0.042750	*-0.590645*	-0.055418	-0.062474
Std. Dev.	0.011149	0.010161	0.010047	0.009989	0.010089	0.010188	*0.022142*	0.009582	0.009668
Skewness	-0.762364	-0.361499	-0.315878	-0.450883	-0.355113	-0.137991	*0.087921*	-0.304443	-0.267648
Kurtosis	7.213183	7.136843	5.366656	6.489972	7.099286	4.673490	*499.9145*	6.414986	6.728836
Jarque-Bera	741.9646*	1521.122*	517.5153*	1120.654*	1492.864*	248.1183*	104755.6*	1037.835*	1223.953*
Probability	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Sum	0.838515	1.226619	1.198181	1.224933	1.219805	1.218815	1.146065	1.226478	1.226878
Sum Sq. Dev.	0.110125	0.213607	0.208856	0.206444	0.210606	0.214762	0.311939	0.189962	0.193382
Observations	887	2070	2070	2070	2070	2070	2068	2070	2070

The Jarque-Bera statistic tests whether a series is normally distributed under the null hypothesis of normality.
* Indicate statistically significant at 5% level.

The Table 4-05 shows the correlation of gold price series in first difference is lower than the correlation of series in level. The correlation of gold spot series in first difference from Mexico and each gold futures or index series is less than the correlation of other spot series and futures or index series.

Table 4-05 Covariance Analysis of Log Gold Price Series in First Difference

Covariance Analysis: Ordinary
Sample (adjusted): 10/07/2004 2/29/2008
Included observations: 887 after adjustments
Balanced sample (listwise missing value deletion)

Correlation Observations	D(FUS^{CBOT})	D(FUS^{NYMEX})	D(FJP^{TOCOM})	D(IML)	D(ISP)
D(SAU)	0.329889	0.318003	0.647398	0.319499	0.323710
	887	2070	2070	2070	2070
D(SMX)	0.115101	0.121472	0.125918	0.124160	0.125265
	887	2068	2068	2068	2068
D(SUK)	0.769377	0.761030	0.348514	0.758539	0.763409
	887	2070	2070	2070	2070
D(SUS)	0.676841	0.671024	0.413470	0.669776	0.673548
	887	2070	2070	2070	2070

This was expected, as theoretically when trading in spot and futures markets or in spot and index markets is perfectly efficient and occurs continuously, a perfectly positive and contemporaneous correlation can exist between prices in the spot-futures and spot-index markets (Hutcheson, 2003). In preliminary results, significant kurtosis coefficient and Jarque–Bera statistics indicate the distributional properties of the price series generally appear non-normal, none of these data sets fit a normal distribution, and thus testing series autocorrelation must be considered. Moreover, high series correlation coefficient suggests significant relationships between futures and spot markets and between index and spot markets in both levels and first difference of gold. The series correlation coefficient between two markets is indicative of market comovements among the prices. This comovement indicates the possible existence of cointegration between the markets and implies one price will be useful in predicting the other price; hence a valid error correcting presentation will exist. The series tend to drift together and not far apart over time (Buhr et al., 2008). Such comovements of the two markets may not necessarily show that movements in one market cause movements in the other. Instead, both markets may be simultaneously responding to a general shock that causes them to move in a certain direction. Thus, further causality tests are necessary to explore the existence as well as the direction of causality (Soydemir and Petrie, 2003).

4.4.2 Silver Market in Chapter 6

The silver daily spot prices from four main producers, manufacturers and traders are Perth Mint in Australia, Handy & Harman (HNH henceforth) in US, London Bullion Market (LBM henceforth) in UK, and Mexico; daily settlement futures prices of the nearest unexpired 3 month silver contracts from the most heavily traded silver contract on Tokyo Commodity Exchange (TOCOM henceforth) in Japan, New York Mercantile Exchange (NYMEX henceforth) and Chicago Board of Trade (CBOT henceforth) in US, and silver indexes from well known investment indexes of Standard & Poor's (S&P's henceforth) and Merrill Lynch are also selected for this research. Details of the data period and source of data are given in Table 4-06 as below.

Table 4-06 Definition of Price Series of Silver

Variable Series Name	Denoted in log levels	Data Source	Data Duration
Closing Futures Prices	FUS^{CBOT}	Chicago Board of Trade (CBOT)	06/10/2004 - 29/02/2008
Closing Futures Prices	FUS^{NYMEX}	New York Mercantile Exchange (NYMEX)	24/03/2000 - 29/02/2008
Closing Futures Prices	FJP	Tokyo Commodity Exchange (TOCOM)	24/03/2000 - 29/02/2008
Index	IML	Merrill Lynch	24/03/2000 - 29/02/2008
Index	ISP	Standard & Poor (S&P)	24/03/2000 - 29/02/2008
Average Daily Spot Prices	SAU	Perth Mint	24/03/2000 - 29/02/2008
Mexico Daily Spot Prices	SMX	Mexico	24/03/2000 - 29/02/2008
PM Fixing Spot Prices	SUK	London Bullion Market Association (LBMA)	24/03/2000 - 29/02/2008
Noon-time Base Prices	SUS	Handy and Harman (H&H)	24/03/2000 - 29/02/2008

All the silver price series used for the analysis are transformed into natural logarithmic values of their actual values, due to original data are collected in different unit measures. Thus, log transformation price that demonstrates change in the value of a price series, is adopted instead of actual price in the analysis. All the logarithmic silver price series in levels and in first differences are plotted in Figures 4-19 and 4-36, which demonstrate all prices and returns of silver move together during examined period; thus it implies a possible strong linear relationship among them. Besides, all graphs show a trend assumption should be including in the unit root tests. Unit root tests in this study allow for intercept and trend as the deterministic components in estimateing regression.

Figure 4-19 Logarithmic Silver Futures Price in Tokyo Commodity Exchange

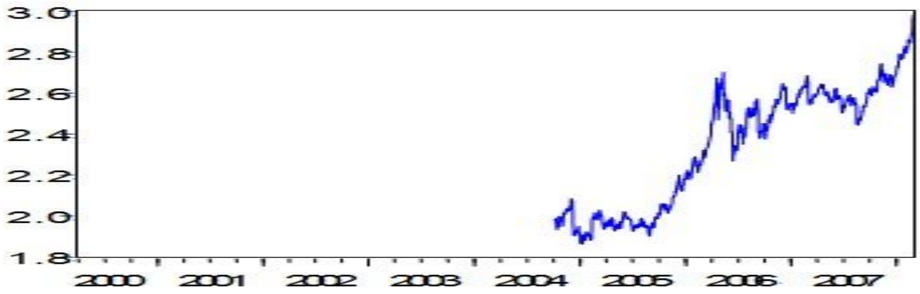


Figure 4-20 Logarithmic Silver Futures Price in Chicago Board of Trade

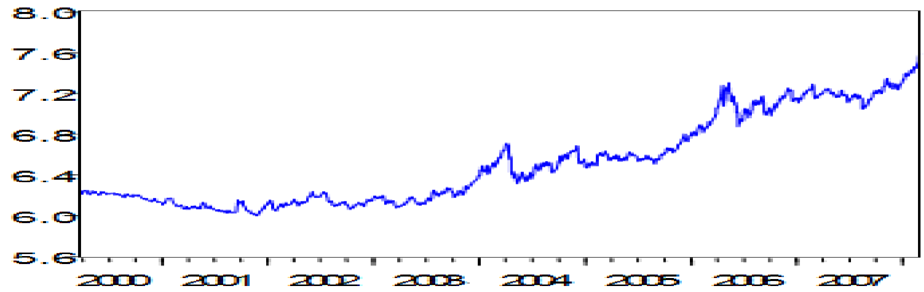


Figure 4-21 Logarithmic Silver Futures Price in New York Mercantile Exchange

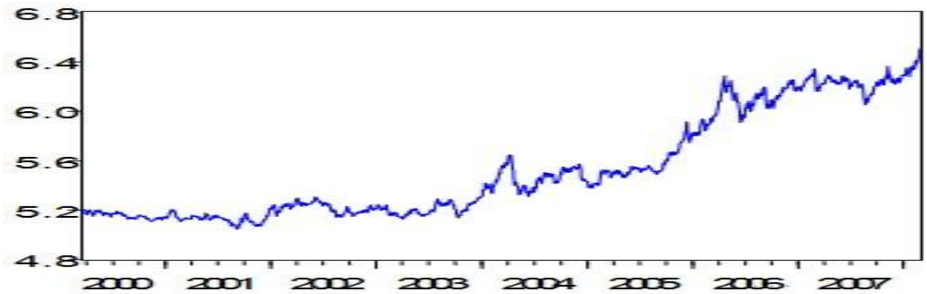


Figure 4-22 Logarithmic Silver Index in Merrill Lynch

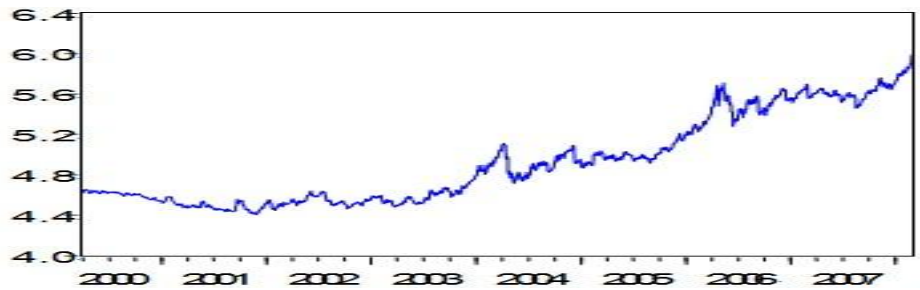


Figure 4-23 Logarithmic Silver Index in S&P

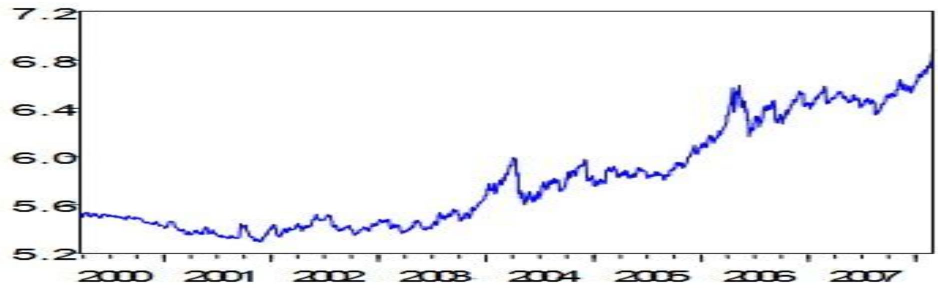


Figure 4-24 Logarithmic Silver Spot Price in Australia

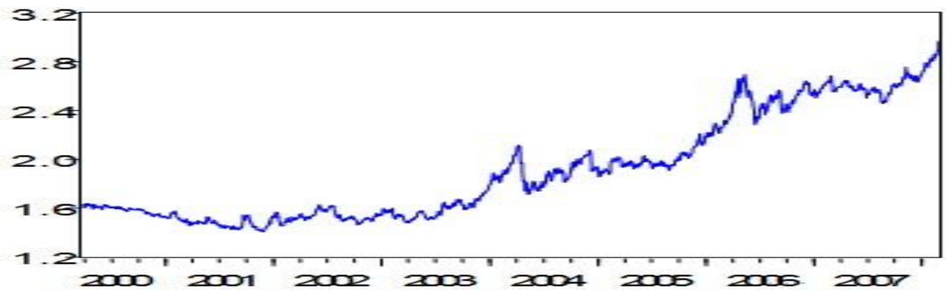


Figure 4-25 Logarithmic Silver Spot Price in Mexico

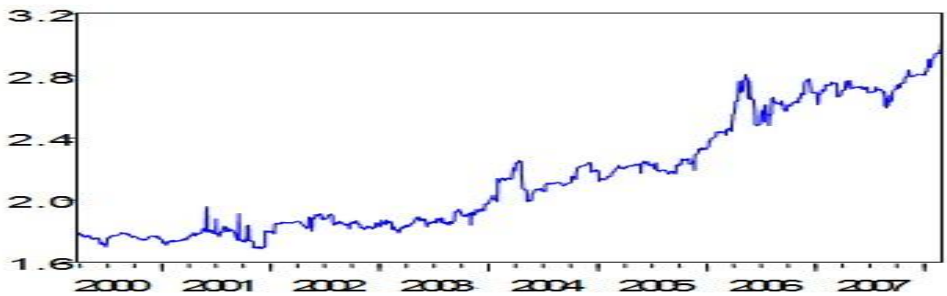


Figure 4-26 Logarithmic Silver Spot Price in UK

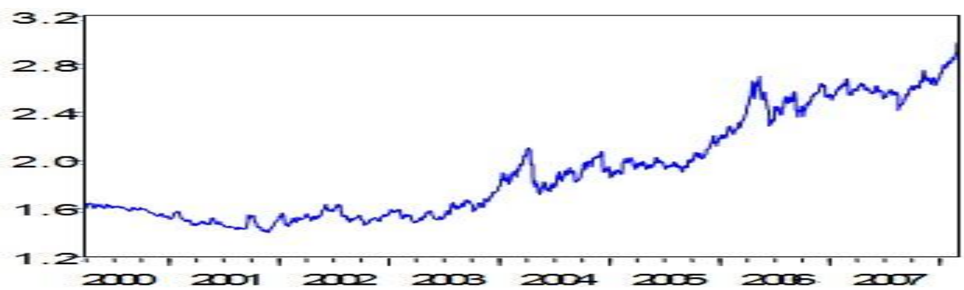


Figure 4-27 Logarithmic Silver Spot Price in US

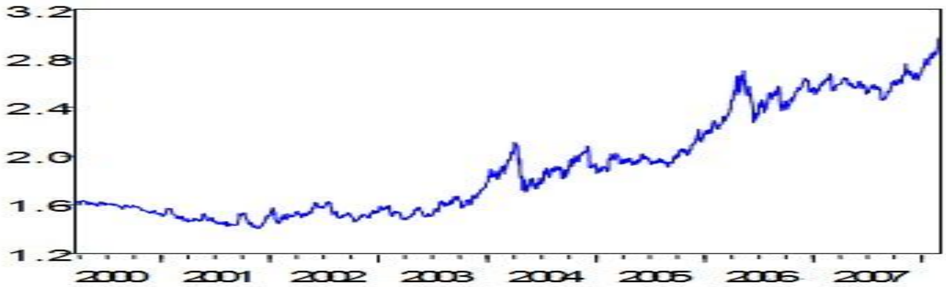


Figure 4-28 Logarithmic Silver futures price in Tokyo Commodity Exchange in First Different

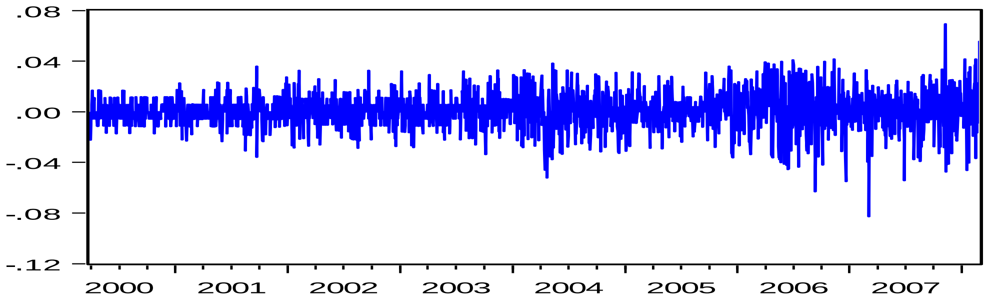


Figure 4-29 Logarithmic Silver futures price in Chicago Board of Trade in First Different

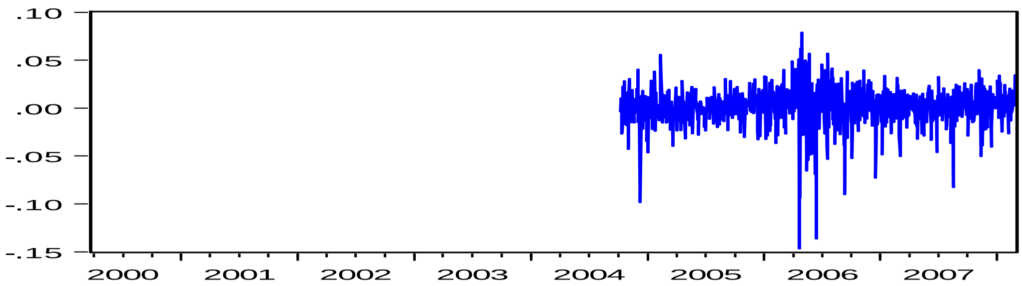


Figure 4-30Logarithmic Silver Futures Price in New York Mercantile Exchange in First Different

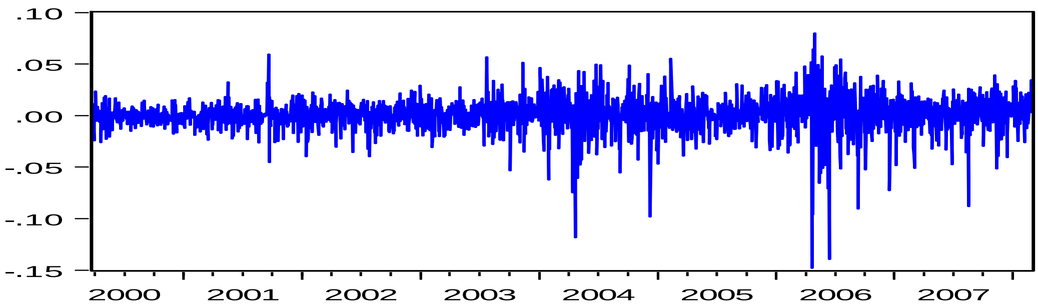


Figure 4-31 Logarithmic Silver Index in Merrill Lynch in First Different

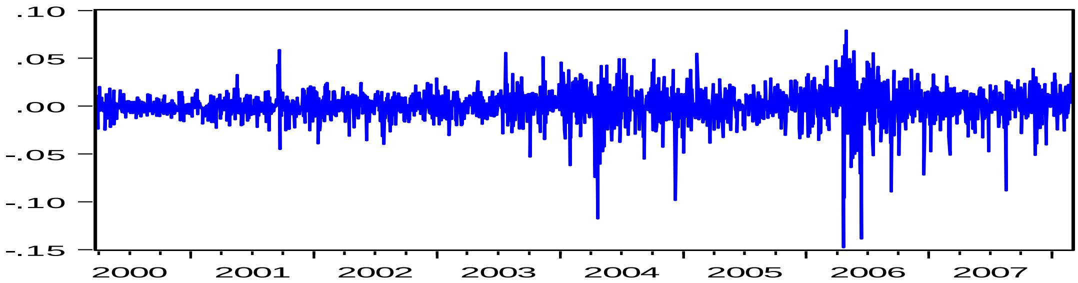


Figure 4-32 Logarithmic Silver Index in S&P in First Different

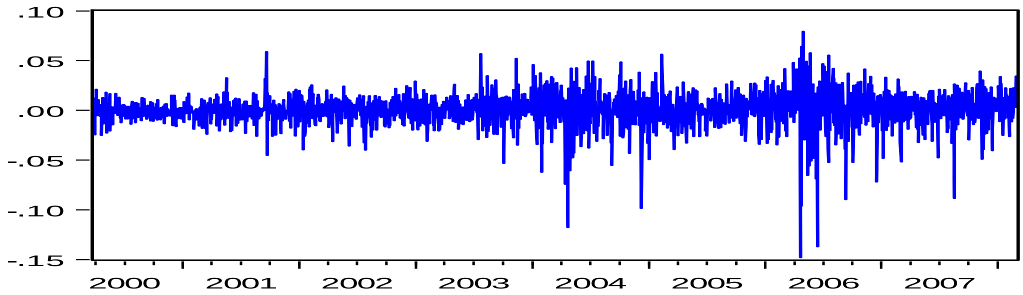


Figure 4-33 Logarithmic Silver Spot Price in Australia in First Different

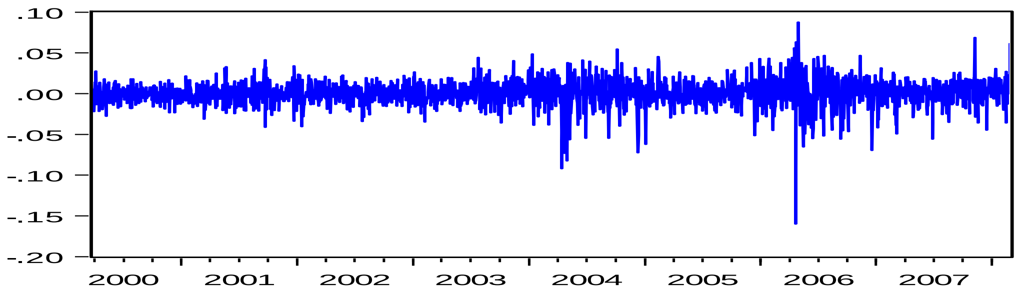


Figure 4-34 Logarithmic Silver Spot Price in Mexico in First Different

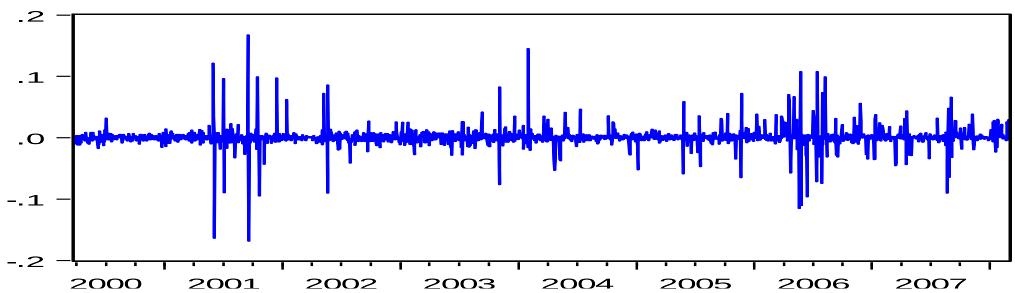


Figure 4-35 Logarithmic Silver Spot Price in UK in First Different

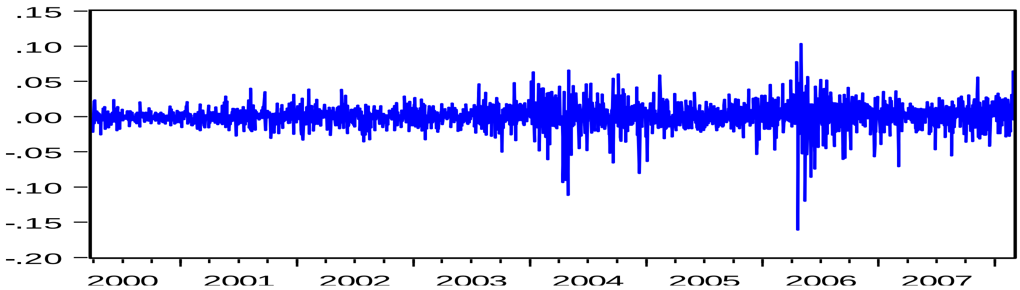
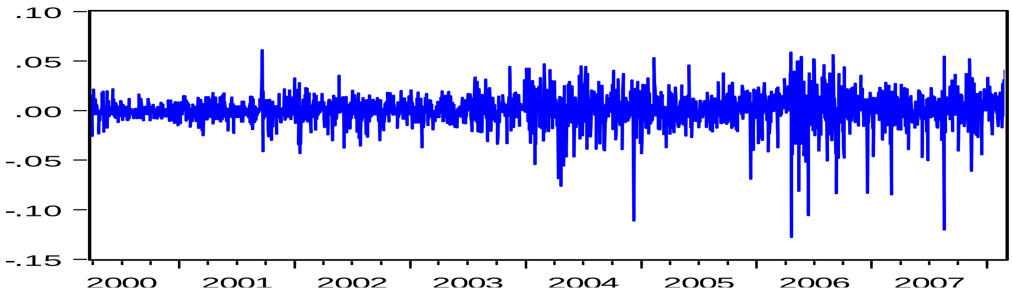


Figure 4-36 Logarithmic Silver Spot Price in US in First Different



Summary statistics and the Jarque–Bera test of normality of series — index, futures and spot prices in both levels and first differences of logarithmic silver price series are analyzed in this section and summarized (Summary Statistics for the Observations of silver) in Table 4-07 and Table 4-09 respectively, followed by Ordinary Covariance Analysis on all series of silver.

The descriptive statistics of data include samples means, medians, maximums, minimums, standard deviations, skewness, kurtosis or degree of excess, sum of square deviations, observations, coefficient of covariation, and the Jacque-Bera statistic and its p-value. Kurtosis measures whether the data are peaked or flat, relative to a normal distribution. Skewness is a measure of symmetry, or more precisely, lack of symmetry. The null hypotheses of skewness and kurtosis are a normally distributed variable cannot be rejected, if skewness coefficient and the kurtosis coefficient are 0 and less than 3 respectively. The Jarque–Bera (1980) test indicates significant departures from normality for variables. The null hypotheses of Jarque–Bera (1980) test that daily distribution of variable is normally distributed cannot be rejected when *p*-values are smaller than the 0.01 level of significance.

Table 4-07 summarized the statistics for all the observations regard to logarithmic price of silver. It shows that the mean of log NYMEX silver futures series in levels is greater than others, and the means of log silver spot price of Australia Perth Mint, LBMA and HNH in levels are similar and lower than the means of the rest. The log silver futures price of CBOT has lowest standard deviation, which is followed log Mexico silver spot price's standard deviation, and the rest of log silver price series has similar standard deviation. The existence of a little positive skew and excessive leptokurtosis is consistent with the standard statistical features of price series. The Jarque-Bera statistics are statistically significant at the 5% level, indicating that none of these series are normally distributed.

Table 4-07

Summary Statistics for the Observations of Log Silver Series In Levels

	FUS^{CBOT}	FUS^{NYMEX}	FJP^{TOCOM}	IML	ISP	SAU	SMX	SUK	SUS
Mean	2.339886	6.520060	5.529650	4.925464	5.807831	1.916212	2.139847	1.912992	1.917227
Median	2.443303	6.416405	5.379897	4.816889	5.700343	1.813195	2.063058	1.813195	1.814825
Maximum	2.985177	7.591256	6.516193	5.994632	6.879778	2.975019	3.026746	2.976549	2.984671
Minimum	1.862218	5.998937	5.043425	4.403605	5.288772	1.403643	1.684545	1.401183	1.398717
Std. Dev.	0.293069	0.428890	0.421429	0.430521	0.429874	0.427944	0.370044	0.428613	0.427057
Skewness	-0.181649	0.639514	0.754533	0.643313	0.642042	0.646041	0.623566	0.645088	0.642527
Kurtosis	1.574749	1.970485	2.006198	1.969526	1.970659	1.968444	1.968068	1.967287	1.972997
Jarque-Bera	80.04303*	232.6260*	281.7359*	234.4790*	233.7136*	235.8855*	226.1032*	235.6669*	233.5139*
Probability	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Sum	2077.819	13503.04	11451.90	10200.64	12028.02	3968.475	4431.622	3961.806	3970.578
Sum Sq. Dev.	76.18410	380.7693	367.6370	383.6715	382.5179	379.0921	283.4506	380.2775	377.5219
Observations	888	2071	2071	2071	2071	2071	2071	2071	2071

The Jarque-Bera statistic tests whether a series is normally distributed under the null hypothesis of normality.
* Indicate statistically significant at 5% level.

Ordinary Covariance Analysis on silver price variables shown in Tables 4-08 reports coefficient of correlation and observations. As expected, the futures and spot markets, or the index and spot markets are significantly positively correlated, and most of variables exhibit correlation higher than 0.99. Silver series correlation coefficients between log Mexico silver spot price and log silver futures prices of TOCOM and NYMEX, and correlation coefficients between log Mexico silver spot price and log silver indexes of S&P's and Merrill Lynch are between 0.98 and 0.99. It means the correlations between above silver markets are less than correlation between the rests of pairwised silver markets.

Table 4-08

Covariance Analysis of Log Silver Price Series In Levels

Covariance Analysis: Ordinary
Sample: 3/24/2000 2/29/2008
Included observations: 2071
Pairwise samples (pairwise missing deletion)

Correlation Observations	FUS^{CBOT}	FUS^{NYMEX}	FJP^{TOCOM}	IML	ISP
SAU	0.998241	0.999381	0.992078	0.999349	0.999363
	888	2071	2071	2071	2071
SMX	0.991371	0.989610	0.988997	0.989211	0.989356
	888	2071	2071	2071	2071
SUK	0.998353	0.999388	0.991980	0.999365	0.999378
	888	2071	2071	2071	2071
SUS	0.999607	0.999847	0.991406	0.999813	0.999823
	888	2071	2071	2071	2071

Table 4-09 summarized the statistics for all the observations regard to logarithmic price of silver in first differenced. It shows log silver futures price of CBOT in first difference has the lowest mean, followed by log silver spot price of Mexico, and the rest of log silver series in first difference has almost similar means. The log silver futures price of CBOT in first difference has the highest standard deviation, whist log silver futures prices of TOCOM has the lowest standard deviation. The skew of log Mexico silver spot price in first difference is to the right, while the skew of the rest series in first difference are to the left, and all these series are far from normal since the kurtosis, or degree of excess coefficients well above 3 with significant Jarque–Bera statistics, the distributional properties of the silver price series in first difference generally appear non-normal.

Table 4-09

Descriptive statistics of first differenced log price series on Silver

	D (FUSCBOT)	D (FUSNYMEX)	D (FJPTOCOM)	D (IML)	D (ISP)	D (SAU)	D (SMX)	D (SUK)	D (SUS)
Mean	0.001132	0.000653	0.000634	0.000650	0.000654	0.000652	0.000593	0.000651	0.000653
Median	0.002062	0.000828	0.000000	0.000835	0.000941	0.001377	0.000000	0.000000	0.000000
Maximum	0.079018	0.080104	0.069361	0.079370	0.079368	0.087730	0.167594	0.103606	0.061288
Minimum	-0.146973	-0.147938	-0.082960	-0.147955	-0.147944	-0.160100	-0.168532	-0.161164	-0.127960
Std. Dev.	0.019817	0.016596	0.014256	0.016483	0.016511	0.015861	0.015602	0.017252	0.016042
Skewness	-1.438713	-1.328091	-0.320857	-1.344964	-1.336229	-0.876978	0.130130	-0.916202	-1.186298
Kurtosis	11.35846	13.08633	4.911192	13.29436	13.09793	10.98973	39.97711	11.78704	11.08847
Jarque-Bera	2888.052*	9383.083*	350.5591*	9764.317*	9410.758*	5771.168*	117936.0*	6949.139*	6128.277*
Probability	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Sum	1.004313	1.351370	1.312186	1.345321	1.352852	1.349708	1.228462	1.347308	1.351517
Sum Sq. Dev.	0.347928	0.569873	0.420479	0.562109	0.564023	0.520471	0.503621	0.615767	0.532471
Observations	887	2070	2070	2070	2070	2070	2070	2070	2070

The Jarque-Bera statistic tests whether a series is normally distributed under the null hypothesis of normality.
*** Indicate statistically significant at 5% level.

Table 4-10 shows that the correlations of log silver series in first difference are lower than the correlation of log silver series in level. The correlation of log Mexico silver spot series in first difference and each silver futures or index series is less than the correlation of other log silver spot series and log futures or log index series.

Table 4-10

Covariance Analysis of First Differenced Log Silver Price Series

Covariance Analysis: Ordinary
Sample (adjusted): 10/07/2004 2/29/2008
Included observations: 887 after adjustments
Balanced sample (listwise missing value deletion)

Correlation Observations	D (FUSCBOT)	D (FUSNYMEX)	D (FJPTOCOM)	D (IML)	D (ISP)
D(SAU)	0.208618	0.206539	0.722569	0.205858	0.203413
	887	2070	2070	2070	2070
D(SMX)	0.160117	0.147632	0.173281	0.149652	0.148513
	887	2070	2070	2070	2070
D(SUK)	0.293644	0.290154	0.630105	0.291012	0.288148
	887	2070	2070	2070	2070
D(SUS)	0.843196	0.839163	0.261738	0.834087	0.839868
	887	2070	2070	2070	2070

In preliminary results, significant kurtosis coefficient and Jarque–Bera statistics indicate the distributional properties of the price series generally appear non-normal, none of these data sets fit a normal distribution, and thus testing series autocorrelation must be considered. Moreover, high series correlation coefficient suggests significant relationships between futures and spot markets and between index and spot markets in both levels and first difference of silver. The series correlation coefficient between two markets is indicative of market comovements among the prices. Besides, the plotted graphs also show that these series tend to move in a similar trend over time. This comovement indicates the possible existence of cointegration between silver markets and implies one price will be useful in predicting the other price; hence a valid error correcting presentation will exist.

4.4.3 Platinum Markets -- Chapter 7

The spot market prices of platinum are obtained from Engelhard in US, London Platinum and Palladium Market (LPPM henceforth) in UK, Perth Mint in Australia, and free market at New York City. The spot prices in what are collected by Engelhard is industrial bullion price set at noon; spot prices of Perth Mint is MID price of its daily trading; spot prices for from LPPM are PM Fix, which is set at 2PM London time; while the spot data are of daily spot closing price obtained from New York's free market. The futures data used in the study consists of daily settlement prices for nearby month futures contracts for platinum are collected from Tokyo Commodity Exchange (TOCOM henceforth) in Japan, New York Mercantile Exchange (NYMEX henceforth). Indexes for platinum are collected from Merlin Lynch and Standard & Poor (S&P henceforth) in US. And all the price series used for the analysis are transformed into natural logarithmic values of their actual values, due to original data are collected in different unit measures, and listed in the Table 4-11 as below.

Table 4-11

Definition of Price Series of Platinum

Variable Series Name	Denoted in log levels	Data Source	Data Duration
Closing Futures Prices	FUS^{NYMEX}	New York Mercantile Exchange (NYMEX)	24/03/2000 - 29/02/2008
Closing Futures Prices	FJP	Tokyo Commodity Exchange (TOCOM)	24/03/2000 - 29/02/2008
Index	IML	Merrill Lynch	24/03/2000 - 29/02/2008
Index	ISP	Standard & Poor (S&P)	24/03/2000 - 29/02/2008
Average Daily Spot Prices	SAU	Perth Mint	24/03/2000 - 29/02/2008
Daily Spot Prices	SNY	New York Free Market	24/03/2000 - 29/02/2008
PM Fixing Spot Prices	SUK	The London Platinum and Palladium Market (LPPM)	24/03/2000 - 29/02/2008
Noon-time Base Prices	SUS	Engelhard	24/03/2000 - 29/02/2008

Thus, log transformation price that demonstrates change in the value of a price series, is adopted instead of actual price in the analysis. All the logarithmic platinum price series in levels and in first differences are plotted in Figures 4-37 and 4-51, which demonstrate all prices and returns of platinum move together during examined period; thus it implies a possible strong linear relationship among them. Besides, all graphs show a trend assumption should be including in the unit root tests. Unit root tests in this study allow for intercept and trend as the deterministic components in estimateing regression.

Figure 4-37 Logarithmic Platinum Futures Price in Tokyo Commodity Exchange

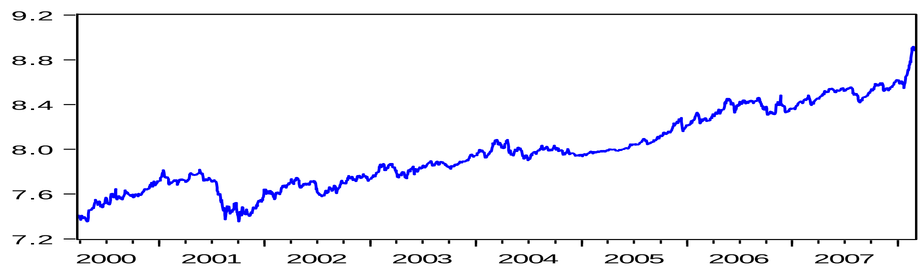


Figure 4-38 Logarithmic Platinum Futures Price in New York Mercantile Exchange

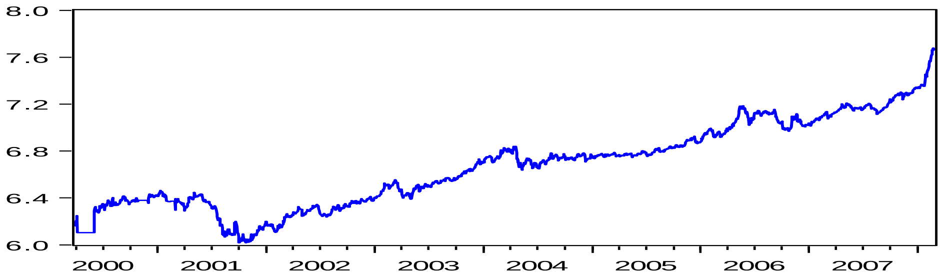


Figure 4-39 Logarithmic Platinum Index in Merrill Lynch

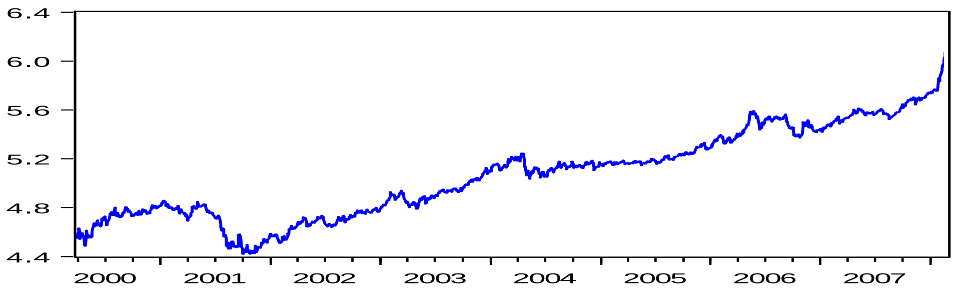


Figure 4-40 Logarithmic Platinum Index in S&P

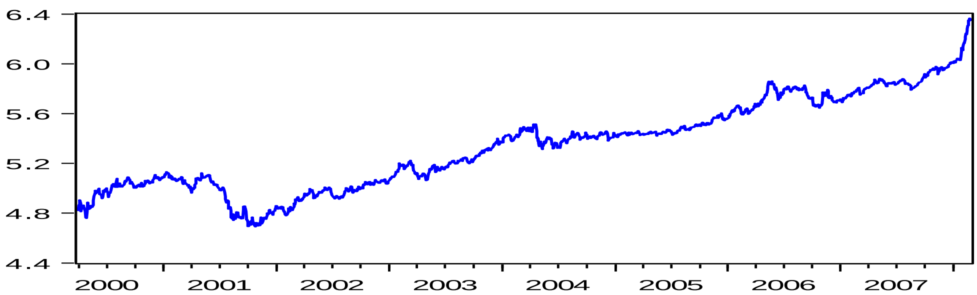


Figure 4-41 Logarithmic Platinum Spot Price in Australia

Figure 4-42 Logarithmic Platinum Spot Price in New York

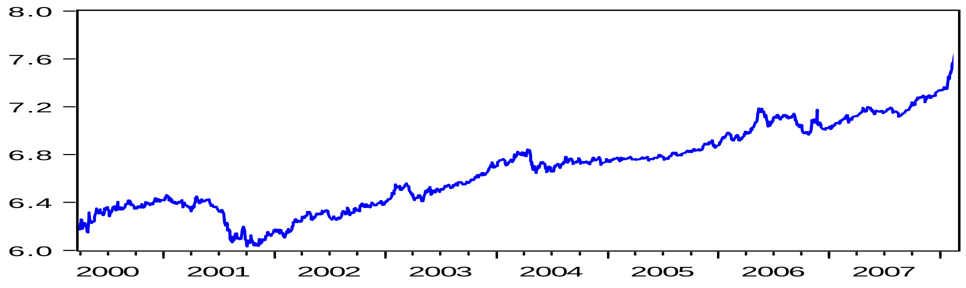


Figure 4-43 Logarithmic Platinum Spot Price in UK

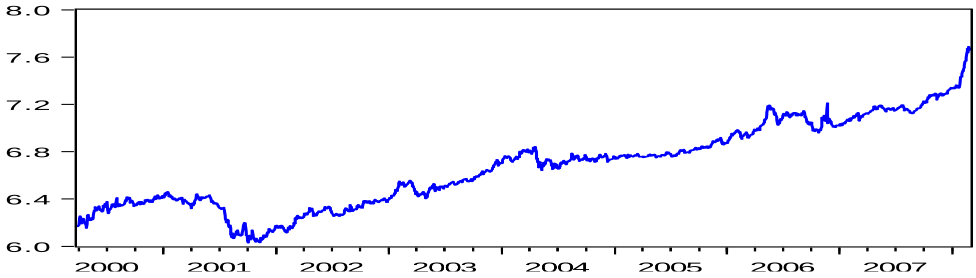


Figure 4-44 Logarithmic Platinum Spot Price in US

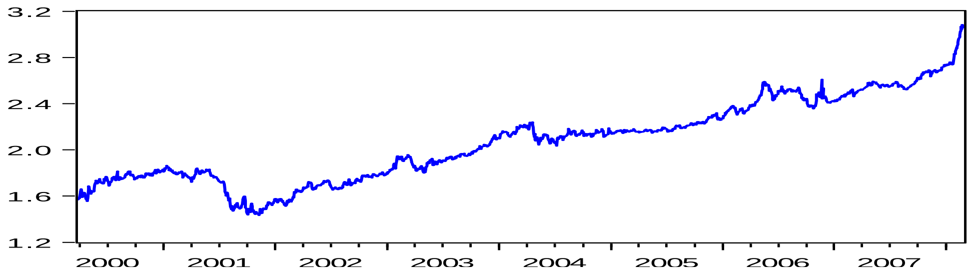


Figure 4-45 Logarithmic Platinum Futures Price in Tokyo Commodity Exchange in First Different

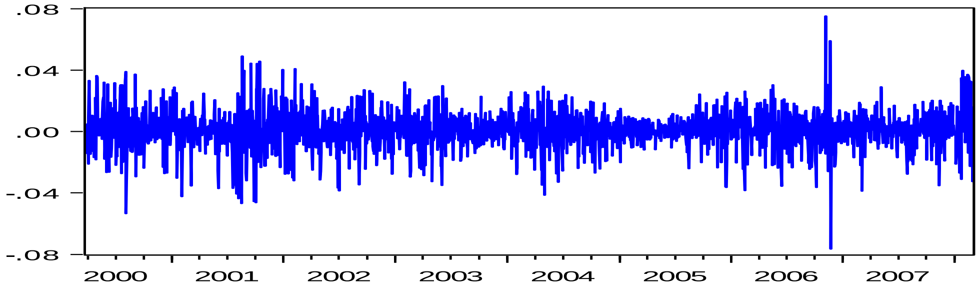


Figure 4-46 Logarithmic Platinum Futures Price in New York Mercantile Exchange in First Different

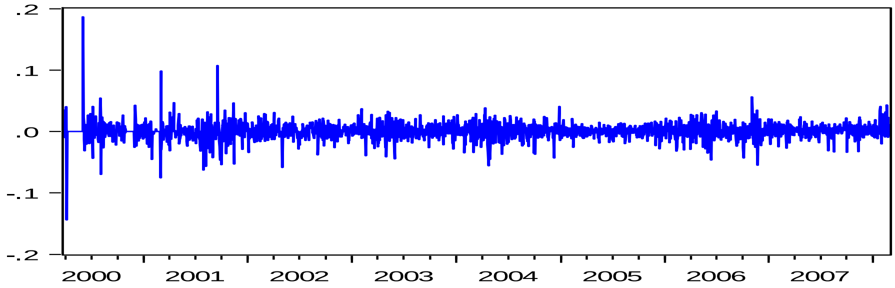


Figure 4-47 Logarithmic Platinum Index in Merrill Lynch in First Different

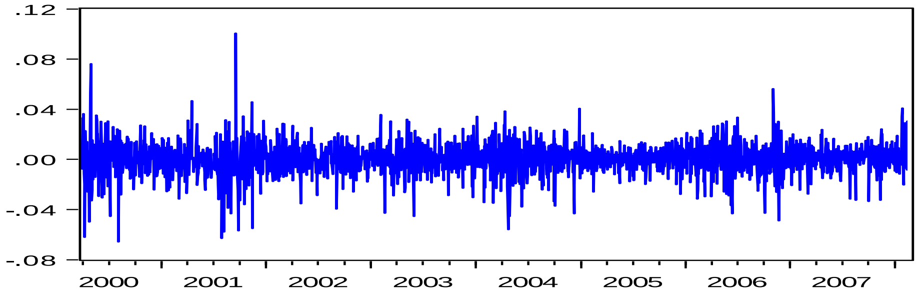


Figure 4-48 Logarithmic Platinum Index in S&P in First Different

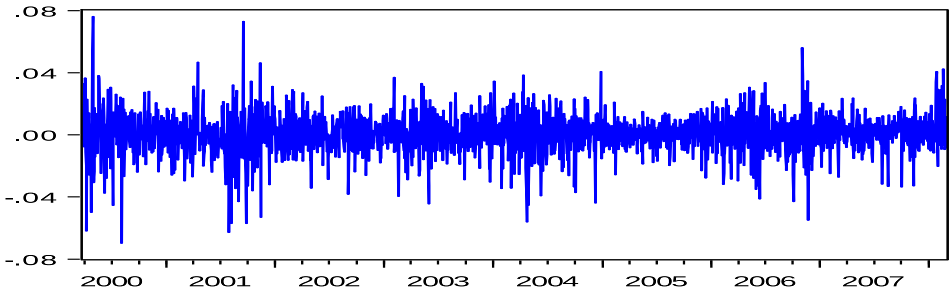


Figure 4-49 Logarithmic Platinum Spot Price in Australia in First Different

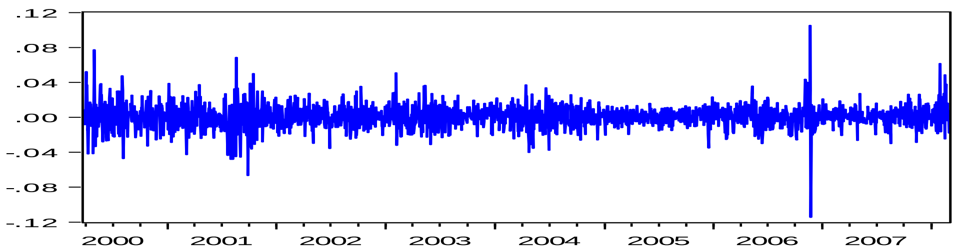


Figure 4-50 Logarithmic Platinum Spot Price in New York in First Different

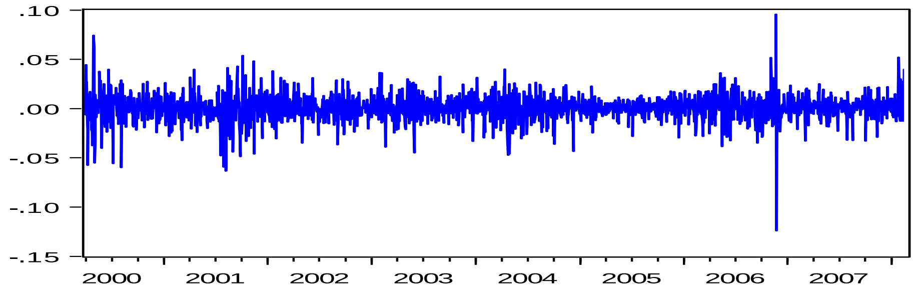


Figure 4-51 Logarithmic Platinum Spot Price in UK in First Different

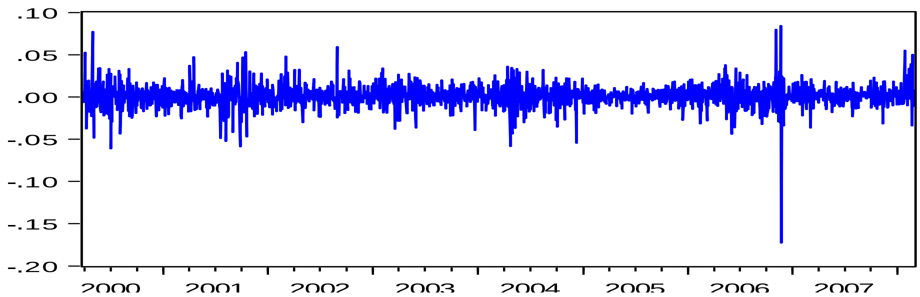
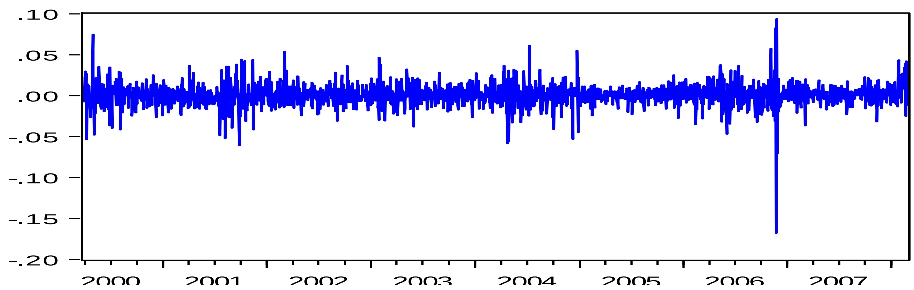


Figure 4-52 Logarithmic Gold Spot Price in US in First Different



Summary statistics and the Jarque–Bera test of normality of series — index, futures and spot prices in both levels and first differences of logarithmic platinum price series are analyzed in this section and summarized (Summary Statistics for the Observations of platinum) in Table 4-12 and Table 4-14 respectively, followed by Ordinary Covariance Analysis on all series of platinum .

The descriptive statistics of data include samples means, medians, maximums, minimums, standard deviations, skewness, kurtosis or degree of excess, sum of square deviations, observations, coefficient of covariation, and the Jacque-Bera statistic and its p-value. Kurtosis measures whether the data are peaked or flat, relative to a normal distribution. Skewness is a measure of symmetry, or more precisely, lack of symmetry. The null hypotheses of skewness and kurtosis are a normally distributed variable cannot be rejected, if skewness coefficient and the kurtosis coefficient are 0 and less than 3 respectively. The Jarque–Bera (1980) test indicates significant departures from normality for variables. The null hypotheses of Jarque–Bera (1980) test that daily distribution of variable is normally distributed cannot be rejected when *p*-values are smaller than the 0.01 level of significance.

Table 4-12 shows the mean of TOCOM platinum futures series in levels is greater than the mean of other series in levels, the mean of US Engelhard platinum spot price in levels is the lowest. The standard deviation of all platinum series in levels has almost similar standard deviation. The existence of a little positive skew and excessive leptokurtosis is consistent with the standard statistical features of price series. The Jarque-Bera statistics are statistically significant at the 5% level, indicating that none of these series are normally distributed.

Table 4-12 Summary Statistics for the Observations of Log Platinum Series In Levels

	FUS^{NYMEX}	FJP^{TOCOM}	IML	ISP	SAU	SNY	SUK	SUS
Mean	6.669479	7.976965	5.069986	5.344528	6.673544	6.673518	6.671993	2.071495
Median	6.710888	7.949444	5.106639	5.380810	6.716292	6.712956	6.714171	2.111425
Maximum	7.679344	8.917445	6.093443	6.365883	7.677780	7.680868	7.687080	3.084201
Minimum	6.016401	7.352441	4.419238	4.691450	6.018958	6.028279	6.028279	1.432701
Std. Dev.	0.360322	0.342759	0.362782	0.360078	0.352720	0.352440	0.353126	0.351363
Skewness	0.223922	0.365471	0.245619	0.246241	0.244015	0.256128	0.251933	0.257260
Kurtosis	2.157459	2.152822	2.133204	2.150258	2.169057	2.195338	2.182422	2.186494
Jarque-Bera	78.56345*	108.0359*	85.65747*	83.23680*	80.13385*	78.51562*	79.58798*	79.95117*
Probability	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Sum	13812.49	16520.30	10499.94	11068.52	13820.91	13820.86	13817.70	4290.067
Sum Sq. Dev.	268.7526	243.1919	272.4343	268.3884	257.5320	257.1229	258.1246	255.5539
Observations	2071	2071	2071	2071	2071	2071	2071	2071

The Jarque-Bera statistic tests whether a series is normally distributed under the null hypothesis of normality.
* Indicate statistically significant at 5% level.

Ordinary Covariance Analysis on platinum price variables in Tables 8-13 reports coefficient of covariance, coefficient of correlation and observations. As expected, the futures and spot markets, or the index and spot markets are significantly positively correlated, and most of variables exhibit correlation higher than 0.99. platinum series correlation coefficients between Japan TOCOM futures and each tested spot prices is between 0.98 and 0.99, which means the correlation between TOCOM futures market and each spot markets is less than correlation between US futures markets and each tested spot markets, and less than correlation between each US index markets and each tested spot markets.

Table 4-13 Covariance Analysis of log Platinum Price Series In Levels
Covariance Analysis: Ordinary
Sample: 3/24/2000 2/29/2008
Included observations: 2071

Correlation Observations	FUS^{NYMEX}	FJP^{TOCOM}	IML	ISP
SAU	0.997829	0.983846	0.999065	0.999121
	2071	2071	2071	2071
SNY	0.998120	0.983581	0.999437	0.999546
	2071	2071	2071	2071
SUK	0.998118	0.983853	0.999360	0.999441
	2071	2071	2071	2071
SUS	0.998060	0.983550	0.999342	0.999437
	2071	2071	2071	2071

Table 4-14 shows the mean of platinum series in first difference are almost similar. The standard deviation of all platinum series in first difference is highest are almost similar. The skew of NYMEX platinum futures price and Australia Perth Mint platinum spot price in first difference are to the right, while the skew of the rest series in first difference are to the left, and since the kurtosis, or degree of excess are significantly different from those of a normal distribution, the distributional properties of the platinum price series in first difference generally appear non-normal. All the series in first difference show high kurtosis with significant Jarque–Bera statistics confirming presence of volatility clustering in all return series.

Table 4-14 Descriptive statistics of first differenced log price series on Platinum

	D (FUS^{NYMEX})	D (FJP^{TOCOM})	D (IML)	D (ISP)	D (SAU)	D (SNY)	D (SUK)	D (SUS)
Mean	0.000727	0.000709	0.000743	0.000741	0.000707	0.000725	0.000725	0.000721
Median	4.20E-05	0.000577	0.000928	0.000836	0.000646	0.000000	0.000000	0.000000
Maximum	0.186780	0.075279	0.100729	0.076223	0.105102	0.095846	0.084278	0.093728
Minimum	-0.144172	-0.076515	-0.065775	-0.069738	-0.114463	-0.124016	-0.172773	-0.167723
Std. Dev.	0.014132	0.012723	0.013106	0.013018	0.013083	0.013265	0.013299	0.013461
Skewness	0.516373	-0.198329	-0.181165	-0.316004	0.058371	-0.387585	-0.829912	-0.684346
Kurtosis	26.83301	5.693935	7.325586	6.399639	10.02946	10.41746	20.59244	19.07295
Jarque-Bera	49083.07*	639.5115*	1625.121*	1031.290*	4263.074*	4797.189*	26931.47*	22443.39*
Probability	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Sum	1.504797	1.467911	1.538086	1.534881	1.462786	1.501473	1.500479	1.493461
Sum Sq. Dev.	0.413201	0.334943	0.355360	0.350648	0.354147	0.364078	0.365955	0.374884
Observations	2070	2070	2070	2070	2070	2070	2070	2070

The Jarque-Bera statistic tests whether a series is normally distributed under the null hypothesis of normality.
*** indicate statistically significant at 5% level.

Table 4-15 shows the correlation of price series in first difference is lower than the correlation of price series in level. The correlation of platinum spot series in first difference from Australia Perth Mint and US NYMEX platinum futures series in first difference is less than the correlation of other platinum spot series and futures or index series in first difference; while, correlation of platinum spot series in first difference from New York free market and S&P platinum index is the highest.

Table 4-15

Covariance Analysis of first differenced log price series on Platinum
Covariance Analysis: Ordinary
Sample (adjusted): 3/27/2000 2/29/2008
Included observations: 2070 after adjustments
Balanced sample (listwise missing value deletion)
Correlation

Observations	D(FUS^{NYMEX})	D(FJP^{TOCOM})	D(IML)	D(ISP)
D(SAU)	0.261450	0.604094	0.315853	0.320285
	2070	2070	2070	2070
D(SNY)	0.706399	0.418153	0.851248	0.864376
	2070	2070	2070	2070
D(SUK)	0.563116	0.535760	0.660050	0.676160
	2070	2070	2070	2070
D(SUS)	0.597280	0.487053	0.712254	0.726436
	2070	2070	2070	2070

In preliminary results, significant kurtosis coefficient and Jarque–Bera statistics indicate the distributional properties of the price series generally appear non-normal, none of these data sets fit a normal distribution, and thus testing series autocorrelation must be considered. Moreover, high series correlation coefficients suggest significant relationships between futures and spot markets and between index and spot markets in both levels and first difference of platinum. The series correlation coefficient between two markets is indicative of market comovements among the prices. Besides, the plotted graphs also show that these series tend to move in a similar trend over time. This comovement indicates the possible existence of cointegration between platinum markets and implies one price will be useful in predicting the other price; hence a valid error correcting presentation will exist.

4.5 Summary

In summary, this research aimed at investigating the nature of long run price discovery and temporal lead lag and causality between financial price and spot price in precious metal industry by probing above research hypotheses, a series of methods are employed, including the unit root tests of Augmented Dickey-Fuller (1979) and Phillips-Perron (Phillips and Perron, 1988) to determine their stationary properties of the series and indicate that they are integteated at 1, and then Johansen’s (1988b) and EG’s (Engle and Granger, 1987) cointegration approaches to examine long-run common behavior of non-stationary time series. If two variables are stationary and cointegrated, it allows analyzing the speed of equilibrium relationship and testing short-term causal relation between the pairwised of gold price series for the period from 2000 to 2008 via VECMs developed by Engle and Granger, and Johansen. Granger causality tests are employed on non-cointegrated financial-spot markets to determine causal directions exist between them.

4.5.1 Timing issues

Before turning to the estimations and results for these precious metals, it is necessary to discuss the effect of the timing of price observations used in the regressions. If a spot price is collected earlier in the day than a futures price, this spot price may to embed ‘fresher’ information than futures price for predicting future spot price. As a result, spot market would appear more important for price discovery than it actually is. On the contrary, if futures price is corrected earlier in the day than spot price, the futures market would appear more important for price discover than it really is.

Futures prices of all three precious metals are from NYMEX and CBOT in US, and TOCOM in Japan. These futures prices and indices are collected shortly after the close of futures trading. Daily indices of all three precious metals are from US S&P’s and Merrill Lynch. Spot prices for all three precious metals are as follows. The spot prices for gold, silver and platinum from Australia Perth Mint are mid average ask and bid prices. TOCOM is open 1 hour earlier than Perth Mint and also close earlier. TOCOM futures prices are collected earlier than the spot prices of Perth mint. It would imply that TOCOM precious metal futures prices may appear to play a significant role in price discovery than it actually is. On the other hand, Perth Mint spot price is collected earlier than US futures prices and indices, which Perth Mint spot price would appear more important than it really is the case.

Spot prices of gold from LBMA are a price fixed at 3pm London time and spot prices of silver from LBMA are a price fixed at noon London time. LBMA gold and silver spot prices are fixed after TOCOM closed, hence, both LBMA gold and silver spot prices may appear less significant than it really is. But because they are collected earlier than US closing futures prices and US indices, LBMA gold and silver spot prices would appear more important than they are the case.

Similar, platinum spot prices from LPPM are a price fixed at 2pm London time, which is later than TOCOM closing futures price, but earlier than US closing futures prices. Hence, LPPM platinum spot prices may appear more significantly than it should be the case in the regressions with US futures price or US indices. And LPPM platinum spot prices may appear less significantly than it may be the case in the regressions with Japan futures prices.

Time in Mexico is 1 hour faster than New York time. Gold and silver closing futures prices from NYMEX and CBOT are collected about 3.30pm New York time and US indices are collected at the end of the trading day. Mexico gold and silver spot prices are average daily spot prices. There is a possibility that the US futures prices, the US indices, and Mexico spot prices are collected at a similar time. Besides, between TOCOM futures prices and Mexico spot prices in gold and silver, Mexico gold and silver spot prices are collected later and would appear less price discovery power than it is in fact.

H&H gold and silver spot prices and Engelhard platinum spot prices are collected at noon New York time. These spot prices are collected before US futures prices collected at 3pm and US indices are collected at the end of the day; hence, these spot prices would appear strong significant for price discovery than they may be the case. As TOCOM is closed while US markets are open, TOCOM precious metals futures price may appear more significant for price discovery than it really is.

Similar, as platinum spot prices from New York free market are collected after TOCOM is closed, TOCOM precious metals futures price may appear more important for price discovery than it really is. New York free market platinum spot prices and the US indices are all collected at the end of the trading day, thus, they may have synchronous data observations. However, New York free market platinum spot prices are daily average price and collected after US futures markets close. Hence, US platinum futures prices may appear more important for price discovery than it really in case. With this background, it can be turn to find the results for the three precious metals in the following chapter.

Chapter 5

Market Efficiency and Price Discovery in Futures, Spot and Index Markets of Gold

5.1 Gold

Gold is the oldest precious metal and interacts with human culture and history since ancient times; for thousands of years, gold has been valued as a global currency, a commodity, an investment and other arts. Following the California gold discovery of 1848, North America became the major gold supplier of world. During 1850 to 1875, more gold was discovered here than in the previous 350 years. By 1890, the gold fields of Alaska and the Yukon were the principal sources of supply and, shortly afterwards, discoveries in the African Transvaal indicated deposits that exceeded even these. The top 10 gold producing countries in 2005 were South Africa, Australia, the US, China, Peru, Russia, Indonesia, Canada, Uzbekistan and Papua New Guinea (Siddiqi, 2007).

As Zhou (2004) states, despite the declining function of gold as currency in the world, the activeness and development of investment activities with gold as the target indicates that gold still has a strong financial nature and remains an indispensable investment tool among all types of investors. Gold is a commodity that combines the attributes of a general commodity, currency and financial commodity, which can be an effective hedge against global inflation (Zhou, 2004). Gold has traditionally been used for jewellery (50%) and investment (38%), and also used in electronics and other industrial sectors. Although, soaring prices of gold have meant its demand for dental uses has been gradually declined, given the shortage of platinum, attempts have been made to use it in catalytic convertors (Edwin, 2011). Moreover, it is also inversely correlated to the US dollar, making it a good currency hedge. Besides, historically, it is negatively correlated stock prices move in opposite direction, investors and central banks have been increasing their investments in gold to diversify their portfolio and reserves during periods of economy turmoil. These might be the reasons why investors around the world are interested in investing in gold.

Gold futures are used as a way for producers and movers of gold to hedge their products against drastic fluctuations in the market, and as a means for speculators to make money off of those same movements in the market. The gold futures market is very attractive for investors, partly because investors do not have to put up the entire amount at the time of entering the contract, instead, they are required to keep a margin money of 5% with the broker, hence trading on margin allows for the relatively small movements of the gold market to translate into large financial gains; and also unlike physical gold, investors are assured of transparency in pricing as there are no making charges or premium involved and units are traded on the exchange (Nathan and Dhanorkar, 2011).

Therefore, in this chapter, price discovery function of selected gold futures price and index is examined by testing a series of hypothesises. After identifying the property of price series, hypothesises of long term price relationship, unbiasedness predictor, price adjustor, and short term lead-lag relationship are tested by cointegration tests and Vector Error Correction Model.

5.2 Univariate Stationary Test Results of Gold Logarithmic Price Series

Non-stationary data are unpredictable and cannot be modelled or forecasted. The results obtained by using non-stationary time series may be spurious and unreliable, leading to poor understanding and forecasting in that they may indicate a relationship between two variables where one does not exist. The solution to the problem is often to transform the time series data, for instance, differencing data, so that it becomes stationary. Hence, in order to receive consistent and reliable results, the characteristics and stationarity of each price series needs to be assessed.

The stationarity of all the index, futures and spot price series of gold in this research is checked based on investigating their integration properties by means of the robust Phillips-Perron (PP henceforth) (Phillips and Perron, 1988) nonparametric tests and the Augmented Dickey-Fuller (ADF henceforth) (Dickey and Fuller, 1979) unit root tests. Bandwidth in PP tests is by Bartlett kernel, and number of optimal lag in the ADF is selected by Schwarz Information Criteria (SIC) (1978). The source of critical values for rejection of the unit root null hypothesis in both tests is provided by Davidson and Mackinnon (1993). In order to make all series stationary, first differences of the series are taken if null cannot be rejected at level.

The results of the PP and ADF unit root tests on Chicago Board of Trade (CBOT henceforth) gold futures price are presented in Table 5-01 and Table 5-02 respectively, where results for $I(1)$ versus $I(0)$ (level prices) allocate in Panel a, and results for $I(2)$ versus $I(1)$ (first price differences) is in Panels b.

In Panels a of Table 5-01 and Table 5-02, it can be seen that the absolute values of computed PP and ADF tests statistics for natural logarithm values of CBOT gold futures price are less than the absolute values of its 10% critical values, thus, the null of unit root is not rejected. It indicates that log-level CBOT gold futures price is non-stationary at the 10% level of significance, and then the PP and ADF tests are performed on the series' first differences.

In logarithmic first differences at Panels b of Table 5-01 and Table 5-02, the absolute values of calculated PP and ADF statistics for CBOT gold futures price are far greater than the absolute values of 1% critical values, and the null of unit root is rejected. The series thus is found to be stationary at 1% significant level or better and the order of integration is said to be one, $I(1)$.

Table 5-01 Phillip-Perron (PP) Unit Root Tests for Logarithmic CBOT Gold Futures Price

$\Delta Y_t = a_1 + \beta_1 Y_{t-1} + \varepsilon_t$

Panel a	Level (lnP)				
Variable	BW	PP Test Statistic	Prob.#	Critical Value at 10%	Stationarity
FUS^{CBOT}	5	-2.095479	0.5471	-3.129619	Non-stationary $I(1)$
Panel b	**First difference (ΔlnP)**				
Variable	BW	PP Test Statistic	Prob.#	Critical Value at 1%	Stationarity
FUS^{CBOT}	7	-30.00091***	0.0000	-3.437508	Stationary $I(0)$

Note:
All the price series are from March of 2000 to February of 2008
Trend and intercept are added in test at level, apart from only intercept is contained in unit root test of CMXC; and only intercept is added at difference level
BW is the bandwidth chosen by Newey-West automatic truncation lag
#MacKinnon (1996) one-sided p-values.
Asterisks denotes: *** Significant at 1% level; ** Significant at 5% level; * Significant at 10% level

Table 5-02
Augmented Dickey-Fuller (ADF) Unit Root Tests for Logarithmic CBOT Gold Futures Price

$$\Delta Y_t = a_0 + \beta_1 Y_{t-1} + \sum_{t=1}^{n} \beta_t \Delta Y_{t-i} + \varepsilon_t$$

Panel a	Level (lnP)				
Variable	Lag Length	ADF Test Statistic	Prob.#	Critical Value at 10%	Stationarity
FUS^{CBOT}	0	-1.997912	0.6012	-3.129619	Non-stationary $I(1)$
Panel b	**First difference (ΔlnP)**				
Variable	Lag Length	ADF Test Statistic	Prob.#	Critical Value at 1%	Stationarity
FUS^{CBOT}	0	-30.00076***	0.0000	-3.437508	Stationary $I(0)$

Note:
All the estimated price series are from March of 2000 to February of 2008
Trend and intercept are added in test at level; and only intercept is added at difference level
Optimal lag lengths chosen by Schwarz Info Criterion (SIC)
Asymptotic critical values are from Davidson and Mackinnon (1993)
#MacKinnon (1996) one-sided p-values.
Asterisks denotes: *** Significant at 1% level; ** Significant at 5% level; * Significant at 10% level

The same story apply on results from testing non-stationarity of all the gold price series, including indexes, futures and spot prices in logarithmic levels and in first differences, presented in Tables X1-01 and Table X1-02 in Appendix I. All the gold price series appear to be non-stationary in log-levels at 10% level of significance and stationary in log first differences 1% level of significance based on the reported p-values. It can conclude that all log-first differenced gold price series are clearly stationary or $I(0)$, thus all log-level gold price series are integrated of the same order or $I(1)$.

Both cointegration (long-run relationship) and lead-lag (short-term causality) relationships are based on the non-stationarity of the time series. Given the results from both PP and ADF unit root tests suggest that all natural logarithm gold price series are integrated at first order, $I(1)$. Thus, it allows testing for cointegration between pairwise log price series to be the logical next step in the empirical analysis.

5.3 Empirical Evidence of H1a: Existence of Long-run Cointegration between Pairwise Gold Markets

Market efficiency also implies two variables should have been at least cointegrated. Cointegration means the same factors that determine the spot price are reflected in the futures price/index, so the two should not drift apart if there is any chance for market efficiency in the long run. For this reason any further investigation for the existence of market efficiency in the case of futures and spot prices, or index and spot price has been abandoned if the null hypothesis of no cointegration between two variables cannot be rejected. On the contrary, the null hypothesis is rejected at the certain significance level.

Cointegration analysis is the preferred tool to analyze comovements between prices series. The use of cointegration analysis and also error correction models enable one to distinguish between short-term and long-run deviations from equilibrium indicative of price discovery, which long-run deviations that account for efficiency and stability (Pizzi et al., 1998).

It fulfilled the necessary condition for cointegration and lead-lag relationship that each of the time series integrates in the same order greater than zero, i.e. $I(1)$. Gold price series of spot and futures, or gold price series of index and spot may move together, and then a linear combination of these price series is stationary. A stationary linear combination of several non-stationary time series indicates a cointegrated long-run relationship of prices among these gold markets. If this is not the case then the two series will tend to drift apart over time and as a result futures price or index will be determined independently from the underlying spot price (Du and Hansz, 2009).

5.3.1 Determination of the Rank of Cointegration on Gold Price Series (*Bivariate cointegration tests*)

Before testing the rank of cointegration, it is necessary to select the number of lags for Cointegration test and Error Correction Model by employing the minimization of the Akaike's Information Criterion (AIC). Minimization of the Schwarz Criteria (SC) is also applied to select alternative lags and double-check the robustness of the empirical findings.

Up to seven lags length is determined by these generally accepted techniques. The appropriate lag length proceeds to test cointegration and to whiten the error term for each of the estimations in relation to gold is presented in Tables X-01 to Tables X-03 in Appendix I.

5.3.2 Results of Cointegration Tests on Gold Price Series

Based on the above analysis, the gold indexes, futures and spot price are all non-stationary variable, but these variables become stationary through the first order difference, which indicates they are $I(1)$ variables, thus providing a possibility for the cointegration relationship between the two variables. Two pairwise cointegration approaches, namely Engle and Granger's (EG's henceforth) and Johansen's, are employed to examine long-run relationship between two price series. The null hypothesis of both estimations is cointegration relationship between two price series does not exist.

In the EG's cointegration method, the series of residual error obtained from the ordinary least square (OLS) regression is tested for the stationarity by using the ADF and PP methods. The results of unit root test for residual error from OLS regression of log Tokyo Commodity Exchange (TOCOM henceforth) gold futures price and log Perth Mint gold spot price are shown in Table 5-03. Both ADF and PP test results show clearly null of non-stationary is rejected at 5% and 1% level of significance respectively, which suggests the residual error is stationary, thus the price series of TOCOM gold futures price and Perth Mint gold spot price are cointegrated. The EG's cointegration results of all the pairwise log gold price series, presented in Table X1-04 to Table X-08 in Appendix I, show residual error from every OLS regression is stationary. It means the existence of cointegration relationship between gold futures and spot prices, and between gold index and gold spot price, given by EG's methods.

Table 5- 03

EG's Cointegration Tests on
Logarithmic TOCOM Gold Futures Price and Logarithmic Australia Perth Mint Gold Spot Price

ADF test: $\Delta Y_t = a_0 + \beta_1 Y_{t-1} + \sum_{t=1}^{n} \beta_t \Delta Y_{t-i} + \varepsilon_t$ PP test: $\Delta Y_t = a_1 + \beta_1 Y_{t-1} + \varepsilon_t$

Variables	ADF Test	PP Test	H_0: $I(1)$	Conclusion
FJP and SAU	-2.381763**	-2.578570***	rejected	Cointegrated

Notes:
*** Statistically significant at 1% level; ** Statistically significant at 5% level

The results of Johansen cointegration test on TOCOM gold futures price and Perth Mint gold spot price are shown in Table 5-04. It is clear from Table 5-04 that for the null hypothesis r ≤ 0 (no cointegrating vector exists) against the alternative r > 0 (at least one cointegrating vector exists), the trace statistics is less than the 5% critical value, indicating the null hypothesis cannot be rejected at the 5% significant level; for the null hypothesis r = 0 (no cointegrating vector exists) against the alternative r = 1 (one cointegrating vector exists), the max eigenvalue test is less than the 5% critical value, indicating the null hypothesis cannot be rejected at the 5% significant level as well. Thus, there is no cointegration equation, and then TOCOM gold futures price and Perth Mint gold spot price are not cointegrated.

Table 5-04

Johansen's Cointegration Tests on
Logarithmic TOCOM Gold Futures Price and Logarithmic Australia Perth Mint Gold Spot Price

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^{p} \ln(1 - \widetilde{\lambda_i})$$

Price Variables	H_0: rank=r	H_1: rank=r	λ_{trace} Statistics	Critical Values	Conclusion
FJP and SAU	r ≤ 0	r > 0	14.96559	25.87211	Non-Cointegrated
	r ≤ 1	r > 1	4.616421	12.51798	Non-Cointegrated

$$\lambda_{Maximal\ Eigenvalue}(r, r+1) = -T \ln(1 - \widetilde{\lambda_{r+1}})$$

Price Variables	H_0: rank=r	H_1: rank=r	λ_{max} Statistics	Critical Values	Conclusion
FJP and SAU	r = 0	r = 1	10.34917	19.38704	Non-Cointegrated
	r = 1	r = 2	4.616421	12.51798	Non-Cointegrated

Notes:
r is the number of cointegrating vectors
* denotes rejection of the hypothesis at the 0.05 level
Critical Value is at 5% significant

In the results of Johansen cointegration test on New York Mercantile Exchange (NYMEX henceforth) gold futures price and Perth Mint gold spot price shown in Table 5-10. The Johansen cointegration test with trace and its results are presented at the left hand side of the Table 5-05, for the null hypothesis H_0: r ≤ 0 (no cointegrating vector exists) against the alternative H_1: r > 0 (at least one cointegrating vector exists), computed trace statistics is greater than the 5% critical value, indicating the null hypothesis can be rejected at the 5% significant level; for the null hypothesis H_0: r ≤ 1 (one cointegrating vector exists) against the alternative H_1: r > 1 (more than one cointegrating vector exists), computed trace statistics is less than the 5% critical value, indicating the null hypothesis cannot be rejected at the 5% significant level. Thus, results of the trace test suggest NYMEX gold futures price and Perth

Mint gold spot price are cointegrated, which means these two gold price series have same stochastic trend and tend to move together over the long run.

Meanwhile, the Johansen cointegration test with eigenvalue and its results are displayed in the right hand side of the Table 5-05, for the null hypothesis H_0: r = 0 (no cointegrating vector exists) against the alternative H_1: r = 1 (one cointegrating vector exists), the computed max eigenvalue statistics is greater than the 5% critical value, indicating the null hypothesis can be rejected at the 5% significant level; for the null hypothesis H_0: r = 1 (one cointegrating vector exists) against the alternative H_1: r = 1 (two cointegrating vectors exist), computed max eigenvalue statistics is less than the 5% critical value, indicating the null hypothesis cannot be rejected at the 5% significant level. Thus, results of the max eigenvalue test suggest that there is one cointegration equation, and thus NYMEX gold futures price and Perth Mint gold spot price are cointegrated. Therefore, results of Johansen cointegration test suggest that there is a long-run equilibrium relationship between NYMEX gold futures price and Perth Mint gold spot price, namely, in the short term the spot and futures prices possibly deviate from the equilibrium, but in the long run they keep up the long-run equilibrium relation.

Table 5-05

Johansen's Cointegration Tests on
Logarithmic NYMEX Gold Futures Price and Logarithmic Australia Perth Mint Gold Spot Price

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^{p} \ln(1-\widetilde{\lambda_i})$$

Price Variables	H_0: rank=r	H_1: rank=r	λ_{trace} Statistics	Critical Values	Conclusion
FUS^{COMEX} and SAU	r ≤ 0	r > 0	127.5556*	25.87211	Cointegrated
	r ≤ 1	r > 1	4.789453	12.51798	Non-Cointegrated

$$\lambda_{Maximal\ Eigenvalue}(r, r+1) = -T \ln(1-\widetilde{\lambda_{r+1}})$$

Price Variables	H_0: rank=r	H_1: rank=r	λ_{max} Statistics	Critical Values	Conclusion
FUS^{COMEX} and SAU	r = 0	r = 1	122.7661*	19.38704	Cointegrated
	r = 1	r = 2	4.789453	12.51798	Non-Cointegrated

Notes:
r is the number of cointegrating vectors
* denotes rejection of the hypothesis at the 0.05 level
Critical Value is at 5% significant

The results of Johansen's cointegration tests on the US gold financial prices and gold price series, presented in Table X1-09 to Table X1-12 in Appendix I, show the null hypothesis of one cointegrating vector exists can be rejected at 5% level of significance. It implies that US gold futures price (of either NYMEX or CBOT) is cointegrated with (any of concerned) gold spot price; US index (of either S&P or Merrill Lynch) is cointegrated with (any of concerned) gold spot price.

On the other hand, the results of Johansen's cointegration tests on Japan gold futures prices and gold price series, presented in Table X1-09 to Table X1-13 at Appendix I, show the null hypothesis of one cointegrating vector exists cannot be rejected at 5% level of significance. It means that Japan TOCOM gold futures price is independent to any of tested gold spot prices with or without overlapped trading hours. It could be as a result of TOCOM is inefficient to international gold spot prices, TOCOM may not be sufficiently open to international investors, and TOCOM is not liquid as gold trading volume has decreased in recently years. But the opposite suggestion given by EG's cointegration conclusions may also indicate that it might be a statistical artefact.

In summary, EG's cointegration tests identify a long-run stable cointegrating relation between TOCOM gold futures price and any price from tested spatial gold cash markets; however, Johansen's cointegration tests show TOCOM gold futures price and gold spot price are not moving together in long run. The different results could be caused by two methods employ different critical values. The absence of cointegration could mean the violation of the necessary condition for the simple efficiency hypothesis, which implies that TOCOM gold futures price is not an unbiased predictor of the spot price at maturity. This implies an absence of a long-run relationship between spot and futures prices, as it was reported in works of Baillie and Myers (1991), Chowdhury(1991), Krehbiel and Adkins (1993), Crodwer and Hamed (1993).

In addition, the same decision given by both EG's and Johansen's cointegration tests is: the null hypothesis that cointegration does not exist is rejected and cointegration relationship has been identified between US gold futures prices (from New York Mercantile Exchange or Chicago Board of Trade) and each of estimated gold spot prices, and also between US gold indexes (from Standard & Poor's or Merrill Lynch) and each of estimated gold spot prices. The identified cointegration that implies the existence of a long-run relationship between two gold price series of futures and spot prices, and of index and spot price from gold market in various countries with none, or partial, or the same trading hours, suggests that these pairwise gold markets share certain long-run information. Although the long-run relationship between above gold price series are not verified in any previous literature, some prior studies on financial time series from different markets in different countries have been found to be cointegrated: cointegrated foreign currency spot and futures rates (Kroner and Sultan 1993); foreign currency spot and forward rates (Barnhart and Szakmary 1991); interest rates in different countries (Akella and Patel 1991); equity markets in different countries (Taylor and Tonks 1989); and stock prices within a given industry (Cerchi and Havenner 1988).

The results are very useful to market participants as well as to regulators. Arbitrage that is the force that brings cointegrated markets together in the long run represents a long-run steady-state equilibrium relationship in a particular market (Karbuz and Jumah, 1995, p.237; Narayan and Smyth, 2005). Arbitrage refers to as any activity that would generate a riskless profit through substitutability between cash and futures markets (Schwartz and Szakmary, 1994). The potential for arbitragers making riskless excess profits on the gold cash markets based on information from their cointegrated futures or index markets is limited in the long run (Maslyuk and Smyth 2009). Moreover, any regulatory initiative on futures market, such as reduction in contract size, changes to margins and others will have its desired impact on cash market. Market participant such as investors thus can use these results to predict impact of shocks to the futures market on cash market (Raju and Karande 2003).

Existence of cointegration is important. While the cointegration relationship confirms the first essential condition for long-run market efficiency, unbiasedness hypothesis, the price discovery efficiency of futures price and index in both the long-run and short-term enable to be tested. Thereby, further tests that are applied to the gold futures prices and indexes address the forecasting ability of TOCOM, NYMEX, CBOT, S&P's and Merrill Lynch respectively, by the set of statistical regressions. Based on the long-run equilibrium relationship, the presence of common stochastic trends further restricts the set of statistical models that can be used to test and implement financial theories (Engle and Granger 1987). In particular, even cointegrated price series share a co-movement in the long run, but deviation from long run equilibrium can occur in the short term. The error correction models can be interpreted as model in which this period’s price change depends on how far the system was out of long-run equilibrium last period, become necessary (Brenner and Kroner 1995). Therefore, once existence of cointegration is confirmed, the condition of long-run integration is imposed, and then a Vector Error Correction Model (VECM henceforth) can be utilised to test for price discovery dynamics in long-run and short-run in the cointegrated gold price.

5.4 Empirical Evidence of H2a: Unbiased Predictor of Gold Future Spot Prices

The term market efficiency is used to explain the relationship between information and share prices in the capital market literature. Efficient markets are commonly thought of as markets in which commodity prices fully reflect all relevant information that is available about the fundamental value of the commodity. Price discovery mechanism refers to absorbing the new information, and reflecting it into the market prices.

The price discovery is one of the most important functions of the futures markets, and the most important effect of futures markets is in providing rational forward prices (Peck 1985). If futures markets are efficient, futures prices must reflect all available information, and then futures prices should provide unbiased predictions of the subsequently observed spot price, which is called the 'unbiasedness' hypothesis. The unbiasedness hypothesis thus has come to be associated with the efficient market hypothesis. And Baillie et al. (1983) suggest that the efficiency hypothesis can be tested by verifying that futures price is an unbiased estimator of the corresponding future spot price. Thus, in order to serve price discovery functions efficiently, the futures markets themselves must conform to the efficient markets hypothesis.

This notion of unbiasedness is conceptually consistent with the notion of speculative efficiency in that the participants in the markets exploit all available information in forming their expectations about the future spot price, or conversely, there are no systematic and exploited profitable opportunities. The unbiasedness hypothesis asserts that the previous periods' futures price of an asset should equal to the current spot price of the asset, and there was long-run market efficiency, thereby reducing the amount of arbitrage to minimum, but increasing speculation when an investor tries to take advantage of an expected price movement forecasted by current futures price, and current futures price could be the best-unbiased estimate of the value of the investment.

If the current futures price is an unbiased predictor of future spot prices, it can provide direct evidence in favour of price discovery occurring primarily in the futures market. Thus, this type of test is one form of the efficient market hypothesis, also called a test of futures market efficiency and is closely associated with the price discovery role. Cointegration of two price series is a necessary condition for market efficiency, since the market efficiency hypothesis implies that the future price is an unbiased predictor of the future spot price. Under the condition that pairwise log gold price series have the long-run equilibrium relationship, or called the cointegration relationship. With cointegration condition, the second necessary condition of the unbiasedness hypothesis is a cointegrating vector (1, -1) between spot and futures prices (Brenner and Kroner, 1995), if gold futures price is an unbiased estimate of gold spot price, the gold futures market is called efficient.

The unbiasedness hypothesis that the futures price at time *t* for a contract with maturity length *j* should be the best and sufficient predictor of the spot price that will prevail in the market at time *t+j*, given the information available to market participants at time *t* can be verified, on the basis of the futures and spot prices are the first order integration and have cointegration relationship by the above analysis, the VECM thus is established to verify the hypothesis of unbiased futures prices.

In the VECM equations (4.23 and 4.24), β_3 and β_4 are the parameters of the cointegrating vector. Assuming two price series fluctuate with equal proportion, a restriction is imposed into VECM respect to the cointegrating parameters—β_3 and β_4 to be (1, -1), which allows conducting asymptotic Chi-square tests on the cointegrating parameters. The null hypothesis of financial price is an unbiased predictor of spot price, where coefficients of cointegrating parameters $\beta_3 = 1\ and\ \beta_4 = -1$ in equation 4.23 and equation 4.24, is rejected if computed statistics of Chi-square is significant.

Various studies have provided evidence for and against the hypothesis, and presently greater weight is accumulating for rejection. Examples of such evidence for commodity futures can be found in Kofi (1973), Martin and Garcia (1981), Hsieh and Kulatilaka (1982), Bigman, Goldfard and Schectman (1983), Canarella and Pollard (1985), to name a few..

Under the restriction of a cointegration vector (1, -1), the null that financial price is the unbiased predictor of spot price can be rejected if Chi-square is significant. Optimal lag length put into VECM is selected by both Schwarz Information Criteria (SIC) and Akaike's Information Criterion (AIC). The empirical results show supporting evidence of cointegration among the series considered in all markets, apart from Japan TOCOM gold futures price. It is because cointegrated non-stationary gold price series are consistent with a necessary condition for the efficient market hypothesis. The estimation results unbiasedness of all pairwise cointegrated non-stationary gold price series are presented in Table 5-06 below.

Table 5- 06

Parameter Restriction on Gold Markets

Gold Markets	Chi-square (1)	Probability	unbiased predictor of spot price
CBOT gold futures price and Mexico gold spot price	5.247069**	0.021984	No
CBOT gold futures price and Australia gold spot price	1.685699	0.194169	Yes
CBOT futures price and US spot price	0.347749	0.555390	Yes
CBOT futures price and UK spot price	0.683457	0.408399	Yes
NYMEX gold futures price and Mexico gold spot price	10.95939***	0.000931	No
NYMEX gold futures price and Australia gold spot price	4.427272**	0.035369	No
NYMEX gold futures price and US gold spot price	0.009671	0.921661	Yes
NYMEX gold futures price and UK gold spot price	0.014454	0.904304	Yes
Merrill Lynch's Gold index and Mexico gold spot price	14.54563***	0.000137	No
Merrill Lynch's gold index and Australia gold spot price	3.364054	0.066634	Yes
Merrill Lynch's Gold index and US gold spot price	4.580281**	0.032342	No
Merrill Lynch's Gold index and UK gold spot price	4.278948**	0.038587	No
S&P's Gold index and Mexico gold spot price	13.35621***	0.000258	No
S&P's Gold index and Australia gold spot price	1.256811	0.262256	Yes
S&P's Gold index and US gold spot price	3.916204**	0.047823	No
S&P's Gold index and UK gold spot price	3.988326**	0.045817	No

Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level;

Empirical evidence suggests that some financial markets, aiding the process of price discovery, are efficient and unbiased in the long-run. These markets are CBOT gold futures price provides useful information on future movements of gold spot prices at Perth Mint, US Handy & Harman (H&H henceforth) and London Bullion Market Association (LBMA henceforth); NYMEX gold futures market is efficient, and plays an important role in price discovery of future gold spot prices at LBMA and H&H; Standard & Poor's (S&P's henceforth) and Merrill Lynch's gold indexes are efficient, and the current S&P's and Merrill Lynch's gold indexes have the predictive power for the future Perth Mint gold spot price. Futures prices have been found performing its fundamental economic function well in previous research, such as Canarella and Pollard (1986) found that the futures prices serve as unbiased estimates of the future spot price using both overlapping and non-overlapping data for the contracts of copper, lead, tin and zinc from London Metal Exchange (LME henceforth) for the period 1975-1983. These results confirm that these gold futures prices and indexes have performed this fundamental economic function well.

On the other hand, it has also found that the parameter restrictions are not satisfied for the cointegrating parameters in the rest of gold markets. Similar results can also been found in past literature, like Goss (1981) rejects futures prices for lead and tin from the LME as forecasting unbisedness using daily price data coving the period 1971-1978. The rejection of unbiasedness indicates that these futures and index markets do not fulfil the price discovery role, hence future spot price cannot be forecasted by the information incorporated in futures prices, and it may shows the financial markets provide informed prices that cannot be embodied in the cash markets. Thus, gold producers may be misled into a costly decision if they make production decisions only on the basis of futures prices or indexes without any adjustment. It also suggests that there are opportunities for consistent speculative profits to be made, because there are still predictive contents in the deviations between financial price and spot price.

5.5 Empirical Evidence of H3a: Price Discovery Role of Gold Futures Prices or Indexes

Previous literature on the price discovery of commodity futures markets has focused on two major questions of the temporal price relationship between futures and cash prices. One is unbiasedness hypothesis that is whether futures price a rational unbiased estimate of future cash prices, has been verified above. The other one is the prediction hypothesis that is whether futures markets, rather than cash markets, the primary informational sources for price discovery, concerns the informational causality between cash and futures prices equivalently, the relative pricing efficiency in futures markets and cash markets (Yang, Bessler and Leatham, 2000).

The price discovery is one of the most important functions of the futures market. It not only means that the futures market can finally forms a reasonable price by collecting the different information, but also represents that the futures price has an important leading role in the market price. The importance of futures market in price discovery thus may depend largely on its relative efficiency (Purcell & Hudson, 1985).

There has been intense debate in the literature over whether the spot or the futures market is the source of the price discovery in commodity markets. Stein (1981) showed that spot and futures prices for a certain commodity are determined simultaneously. But Garbade and Silber (1983) argue that price discovery takes place in the most liquid market. Futures markets are considered having low transactions costs, contributing by its uniform contract terms, clearinghouse offset and third-party guarantee, and low margins, thereby increases market liquidity and price efficiency, and facilitate increased speculation on commodity prices (Peck 1985). The purpose to identify the price discovery role of gold futures or index markets is for international market practitioners making the optimal commercial decisions on production, consumption, storage of gold, and speculation in response to the prices reflected on gold markets, with some knowledge of the conditions in gold index, futures and spot markets.

Price discovery has been examined comprehensively by a series of the economic models, in order to reflect the operating efficiency in the futures market (Feng, Liu, Lai, Deng 2007). The identified existence of cointegration relationship implies that the three types gold markets—futures markets, index markets and cash markets, could equally provide price discovery in long run. In this research, the hypothesis of new information transmit much faster in the gold futures or index markets, and futures/index markets contribute to the discovery of a unique and common unobservable price, which is the efficient price, rather than spot price, are tested by VECM based on both Johansen (1988a) and EG cointegration techniques. The optimal lags in VECM are selected by the minimization of the Akaike information criterion; minimization of the Schwarz Bayesian information criterion is also employed to select alternative lags and double-check the robustness of the empirical findings.

In the Johansen's VECM equation 4.19 and equation 4.20, a_1 and a_2 are the speed of adjustment parameters that is to measure the speed with which deviations from the long-run relationship are corrected by changes in the spot and futures prices. If the coefficient of a is significant in both spot (s_t) and futures prices (f_t) equations, thus both spot and futures prices adjust to eliminate all deviations from their long-run relationship. The larger a in absolute form has represented the higher level of adjustment and greater response of the series to deviations from long-run equilibrium and the price gap between the series will be very stable. Therefore, the absolute value of a_1 is expected to be greater than the absolute value of a_2, in order to accept the hypothesis that futures or index markets play an important price discovery role.

Table 5- 07 Johansen's Vector Error Correction Model on logarithmic CBOT gold futures price and logarithmic Australia spot price

$\Delta fus_t = a_{fus} + a_2[sau_{t-1} - \beta_2 fus_{t-1}] + \sum_{i=1}^{k} \rho_{21}\Delta sau_{t-i} + \sum_{j=1}^{k} \rho_{22}\Delta fus_{t-j} + e_t$				$\Delta sau_t = a_{sau} + a_1[sau_{t-1} - \beta_1 fus_{t-1}] + \sum_{i=1}^{k} \rho_{11}\Delta sau_{t-i} + \sum_{j=1}^{k} \rho_{12}\Delta fus_{t-j} + u_t$			
FUS_t^{CBOT}	Coefficient	Standard Error	t-Statistics	SAU_t	Coefficient	Standard Error	t-Statistics
β_1	1			β_2	-0.998570***	0.00110	-907.892
μ_1	0.000816**	0.00039	2.08830	μ_2	0.000766***	0.00023	3.29775
a_1	-0.296130**	0.13553	-2.18494	a_2	0.639925***	0.08056	7.94392
ρ_{111}	0.257658**	0.13093	1.96790	ρ_{211}	0.249884***	0.07782	3.21106
ρ_{112}	0.206949*	0.12272	1.68628	ρ_{212}	0.098377	0.07294	1.34868
ρ_{113}	0.260013**	0.11204	2.32081	ρ_{213}	0.041578	0.06659	0.62439
ρ_{114}	0.164222	0.09989	1.64401	ρ_{214}	0.104519*	0.05937	1.76042
ρ_{115}	0.136507	0.08608	1.58579	ρ_{215}	0.002469	0.05116	0.04825
ρ_{116}	0.033735	0.06583	0.51247	ρ_{216}	-0.021363	0.03913	-0.54603
ρ_{121}	-0.220653*	0.12756	-1.72973	ρ_{221}	-0.127212	0.07582	-1.67783
ρ_{122}	-0.200535*	0.11806	-1.69854	ρ_{222}	-0.050410	0.07017	-0.71838
ρ_{123}	-0.172370*	0.10414	-1.65523	ρ_{223}	-0.099326	0.06189	-1.60476
ρ_{124}	-0.104833	0.09251	-1.13315	ρ_{224}	-0.000875*	0.00046	-1.89255
ρ_{125}	-0.172635**	0.07535	-2.29099	ρ_{225}	-0.022246	0.04479	-0.49670
ρ_{126}	-0.038901	0.04141	-0.93939	ρ_{226}	0.015885	0.02461	0.64541
R^2	S.D. dependent	S.E. equation	F-statistic	R^2	S.D. dependent	S.E. equation	F-statistic
0.023170	0.011158	0.011110	1.581880	0.616704	0.010587	0.006603	107.3044

Notes

In the estimated VECM results, β_1 and β_2 cointegration parameters, μ_1 and μ_2 are intercepts, a_1 and a_2 are coefficients for the error correction term, ρ_{11i} is the coefficient for ΔFUS_t^{CBOT} at lag i in the ΔFUS_t^{CBOT} equation, ρ_{12i} is the coefficient for ΔSAU_t at lag i in the ΔFUS_t^{CBOT} equation, ρ_{21i} is the coefficient for ΔFUS_t^{CBOT} at lag i in the ΔSAU_t equation, ρ_{22i} is the coefficient for ΔSAU_t at lag i in the ΔSAU_t equation

Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level; * Statistically significant at 10% level

The results of the Johansen's VECM on CBOT gold futures price and Australia's gold spot price displayed in the Table 5-07 above, where the coefficients statistics of adjustment parameters a are significant at 1% level in both futures and spot prices equations. That shows a sustainable long-term equilibrium is attained by closing the gap between CBOT gold futures price and Australia's gold spot price. The absolute value of a_2 from spot price equation is greater than the absolute value of a_1 from futures price equation suggests that CBOT gold futures price makes greater contribution to price discovery than Australia's gold spot price does.

The adequacy of the model is checked by analysing the standardized residuals. After standardising there should be no autocorrelation in the residuals and squared residuals, if the model is well specified. This diagnostic check is performed by analysing the Lagrange multiplier (LM henceforth) tests of the series. The lag lengths chosen to whiten the error term and as tests for autocorrelation LM tests for the presence of autocorrelation up to the 12th order are reported in Table 5-08, and the p-values of the LM test are shown that no problems with autocorrelated residuals occur.

Table 5- 08
VEC Residual Serial Correlation LM Tests
Null Hypothesis: no serial correlation at lag order h
Sample: 3/24/2000 2/29/2008
Included observations: 881

Lags	LM-Stat	Prob	Lags	LM-Stat	Prob
1	2.277808	0.6848	7	2.530872	0.6391
2	5.905213	0.2063	8	3.833884	0.4290
3	10.89346	0.0278	9	11.72998	0.0195
4	0.989284	0.9114	10	4.638459	0.3264
5	1.010053	0.9083	11	1.351237	0.8526
6	2.231751	0.6932	12	5.829103	0.2123

Probs from chi-square with 4 df.

Embedding the residuals from the OLS equilibrium regression into the standard VECM, a_1 and a_2 in EG's bivariate VECM equitation 4.17 and equitation 4.18 indicate the adjustment speed of futures-index and spot prices respectively. The EG's VECM estimation results on CBOT gold futures price and Australia's gold spot price displayed in Table 5-09 show the statistical significance and absolute value of adjustment parameters a_1 and a_2 in futures and spot prices equations respectively indicate both CBOT gold futures price and Australia Perth Mint gold spot price contribute to price discovery, but CBOT gold futures price makes greater effort on resuming equilibrium. The p-values of the LM test in Table 5-10 show a presence of weak serial correlation in residuals, which indicates the residuals appear reasonable well behaved.

Table 5- 093

EG's Vector Error Correction Model on
logarithmic CBOT gold futures price and logarithmic Australia gold spot price

$\Delta sau_t = a_{sau} + a_1 \widehat{e_{t-1}} + \sum \rho_{11}(i)\Delta sau_{t-i} + \sum \rho_{12}(i)\Delta fus_{t-i} + \varepsilon_{st}$				$\Delta fus_t = a_{fus} + a_2 \widehat{e_{t-1}} + \sum \rho_{21}(i)\Delta sau_{t-i} + \sum \rho_{22}(i)\Delta fus_{t-i} + \varepsilon_{ft}$			
FUS_t^{CBOT}	Coefficient	Standard Error	t-Statistics	SAU_t	Coefficient	Standard Error	t-Statistics
β_1	1			β_2	-0.999051***	4.5E-07	-2244665
μ_1	0.000770***	0.00023	3.31937	μ_2	0.000764***	0.00023	3.28767
a_1	-0.361419***	0.08043	-4.49356	a_2	0.639142***	0.08051	7.93895
ρ_{111}	0.252008***	0.07768	3.24406	ρ_{211}	0.252287***	0.07776	3.24455
ρ_{112}	0.102599	0.07289	1.40762	ρ_{212}	0.102723	0.07296	1.40798
ρ_{113}	0.048140	0.06672	0.72150	ρ_{213}	0.048183	0.06679	0.72145
ρ_{114}	0.106894*	0.05933	1.80180	ρ_{214}	0.106996*	0.05938	1.80179
ρ_{115}	0.006365	0.05122	0.12426	ρ_{215}	0.006371	0.05127	0.12427
ρ_{116}	-0.019663	0.03912	-0.50268	ρ_{216}	-0.019662	0.03915	-0.50218
ρ_{121}	-0.130837*	0.07578	-1.72654	ρ_{221}	-0.130999*	0.07585	-1.72703
ρ_{122}	-0.055105	0.07022	-0.78480	ρ_{222}	-0.055158	0.07028	-0.78480
ρ_{123}	-0.101761	0.06188	-1.64442	ρ_{223}	-0.101867	0.06194	-1.64456
ρ_{124}	-0.009879	0.05501	-0.17956	ρ_{224}	-0.009905	0.05507	-0.17987
ρ_{125}	-0.025933	0.04492	-0.57730	ρ_{225}	-0.025964	0.04496	-0.57744
ρ_{126}	0.014845	0.02464	0.60244	ρ_{226}	0.014837	0.02466	0.60154
R^2	S.D. dependent	S.E. equation	F-statistic	R^2	S.D. dependent	S.E. equation	F-statistic
0.655824	0.011158	0.006599	117.8684	0.616978	0.010587	0.006605	99.64064

Notes
In the estimated VECM results, β_1 and β_2 cointegration parameters, μ_1 and μ_2 are intercepts, a_1 and a_2 are coefficients for the error correction term, ρ_{11i} is the coefficient for ΔFUS_t^{CBOT} at lag i in the ΔFUS_t^{CBOT} equation, ρ_{12i} is the coefficient for ΔSAU_t at lag i in the ΔFUS_t^{CBOT} equation, ρ_{21i} is the coefficient for ΔFUS_t^{CBOT} at lag i in the ΔSAU_t equation, ρ_{22i} is the coefficient for ΔSAU_t at lag i in the ΔSAU_t equation
Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level; * Statistically significant at 10% level

Table 5- 10

VEC Residual Serial Correlation LM Tests
Null Hypothesis: no serial correlation at lag order h
Sample: 3/24/2000 2/29/2008
Included observations: 881

Lags	LM-Stat	Prob	Lags	LM-Stat	Prob
1	4.122594	0.3897	7	6.660471	0.1550
2	10.54151	0.0322	8	2.641594	0.6195
3	4.116805	0.3904	9	13.23129	0.0102
4	3.649844	0.4555	10	3.759903	0.4395
5	2.404797	0.6618	11	5.138996	0.2733
6	5.162679	0.2710	12	5.978122	0.2008

Probs from chi-square with 4 df.

The results of EG’s and Johansen’s VECM estimations in relation to gold price series are displayed in Table X1-14 to Table X1-22 in Appendix I. Both types of VEC estimations support that CBOT gold futures price is the main contributor to price discovery than Perth Mint gold spot price and H&H gold spot price; and CBOT gold futures price is the sole leader to Mexico gold spot price and LBMA gold spot price in price discovery; NYMEX gold futures price is the main contributor to price discovery than any tested gold spot price; Merrill Lynch gold index is the main contributor to price discovery to Mexico gold spot price and H&H gold spot price; Merrill Lynch gold index leads Perth Mint gold spot price and LBMA gold spot price respectively in price discovery; and S&P's gold index is the main contributor to price discovery rather than gold spot prices of Perth Mint, H&H and LBMA; meanwhile, S&P's gold index leads Mexico gold spot price in price discovery.

As Johansen’s VECM on TOCOM gold futures price cannot be carried out due to absence of cointegration in previous step, EG’s VEC estimations support TOCOM gold futures price is the main contributor to price discovery rather than gold spot prices of H&H, Mexico and LBMA, apart from TOCOM gold futures price makes almost equally efforts to price discovery as Perth Mint gold spot price in the long run. Finally, the diagnostic statistics of Lagrange Multiplier tests following each of VEC estimations reveal that the residuals are generally well behaved and in particular free from autocorrelation problems, which indicate all the error-correction estimated models are appropriate.

Gold futures prices and indexes have a greater speed of adjustment to the previous period’s deviation from long-run equilibrium than the gold spot price series has been found in all the EG’s and Johansen’s VECM results. Therefore, the hypothesis that futures prices and indexes are the primary informational sources of spot prices during 2000 to 2008 fails to be rejected for gold. It suggests that price change in gold futures prices and gold indexes markets lead price changes in gold cash markets more frequently than the opposite in the long run, while the price discovery function may work to a certain extent on gold cash markets during estimated period. With an exception, the equal importance of TOCOM gold futures price and Perth Mint gold spot price as an informational source in the long run equally important. Besides, the influence of the change of gold futures price or gold index is greater than that of gold spot price on the market price, which reflects the importance of gold futures markets of

CBOT, NYMEX, and TOCOM, and gold index markets of Standard & Poor's and Merrill Lynch’s, to stabilize the market price, and these gold futures and index markets are efficient.

These results that the price discovery is achieved in the futures market, consistent with a number of research, such as Kawaller (1987), Harris (1989), Stoll and Whaley (1990), Chan (1990), Teppo (1995), Arshanpalli and Doukesh (1997), Alphones (2000), Lafuente (2002), Tenmozhi (2002), Kavussanos (2003), So and Tse (2004), and Bhatia (2007). Kavussanos and Nomikos (2003) define the lower cost transaction in the futures markets may be the reason that futures markets seem to be informally more efficient than their corresponding spot markets. These results imply that there is causality from gold futures and index market to gold cash markets, in other words, the gold futures and index markets lead gold cash markets, with gold futures prices and indexes enclosing valuable information about subsequent gold spot prices.

5.6 Empirical Evidence of H4a: Short-term Causality of Gold Price Series

In perfect efficiently and ideally organized futures and cash markets, informed investors are indifferent among trading in either market, as the new information disseminates in both markets at the same time. That means that changes in the logarithm of futures and spot price (futures and spot returns) would be estimated to be perfectly contemporaneous correlated and non cross-autocorrelated (Stoll and Whaley, 1990). In such environment the negotiation of futures contracts in relation with the underlying spot market would not provide arbitrage opportunities.

However, the various market frictions, such as the institutional settings of the financial markets, the differences in transaction costs and the market microstructure effects may lead the returns in one market to lead or lag the other market. Therefore, arbitrage profits may be plausible. As indicated by Chan and Chung (1993), arbitrage is a strategy according to which, investors seek to earn from the distribution among prices in the futures and spot markets for commodities. Sofianos (1993) states that the lead lag relationship among futures and spot market is significant for arbitrageurs who demand to “complete both legs of an arbitrage transaction”.

The cointegration test results reveal that there is a long run relationship between pairwise gold price series. Hence, a VECM can be employed to gauge insights into short-term causal dynamics linkage in the pairwise gold markets. The coefficients statistics of lead and lag ρs in both Johansen's VECM (equation 4.19 and equation 4.20) and EG's VECM (equation 4.17 and equation 4.18) are the key indicator for the price dynamics and direction of causal relationship in the short-term. If Δs_t represents spot price and Δf_t represents futures price in VECM equations, the statistical significant ρ_{11i} indicates change in past spot price affects current change in itself, the statistical significant ρ_{12i} indicates change in past futures price affects current change in spot price, statistical significant ρ_{21i} indicates change in past spot price affects change in current futures price, statistical significant ρ_{22i} indicates change in past futures price affects current change in itself.

Futures and index markets are considered more efficient than their corresponding cash market, because of cost of transaction, capital required and other aspects, and gold futures and index markets have been found play a leading role of price discovery in the long run, thereby the hypothesis of short-term price discovery dynamics is that gold futures and index markets lead gold cash market in the short run respectively. Thus, more statistical significant ρ_{21i} are expected than statistical significant ρ_{12i} from VECM results.

As result of Johansen's VECM estimation on CBOT gold futures price and Australia Perth Mint gold spot price shown in the Table 5-07, with the lag length decided by Akaike information criterion and Schwarz Bayesian information criterion. The statistically significant coefficients of lags ρ_{11i} and ρ_{12i} in first differences CBOT gold futures price equation show the past move of Perth Mint gold spot price and CBOT gold futures price has impact on current move of CBOT gold futures price respectively; coefficients of ρ_{21i} and ρ_{22i} in first differences Perth Mint gold spot price equation are statistically significant states the past move of CBOT gold futures price and Perth Mint gold spot price has impact on current move of Perth Mint gold spot price respectively. These number and figures of statistic significant lags ρ indicate that Perth Mint gold spot price has greater causality power over CBOT gold futures price based on their bidirectional causality relationship.

As EG's VECM estimation on CBOT gold futures price and Australia Perth Mint gold spot price shown in the Table 5-09, with the lag length decided by Akaike information criterion and Schwarz Bayesian information criterion. The statistically significant coefficients of lags ρ in both equations show past move of Australia Perth Mint gold spot price has impact on current move of itself and CBOT gold futures price; and the past move of CBOT gold futures price has impact on current move of itself and Australia's gold spot price. These figures of lags ρ indicate CBOT gold futures price and Perth Mint gold spot price influence each other with similar causality power based on their bidirectional causality relationship.

The bidirectional causality relationship between CBOT gold futures price and Perth Mint gold spot price has been verified by both Johansen's and EG's VECMs, which consistent with previous studies of Chan (1991), Tang, et al (1992), Gordon, et al (1992), Turkingston and Walse (1999), Zou and Pinfold (2001) and Raju and Karande (2003) that the bi-directional causality exists between both the markets and price discovery takes place in both futures and cash markets.

The results of all the Johansen's and EG's VECM applied on cointegrated gold price series are displayed in Table X-14 to Table X-22 in Appendix I. The hypothesis that gold futures and index markets lead gold cash market cannot be rejected in following market, based on either unidirectional or bidirectional causality relationship, confirmed by both VECM approaches.

CBOT gold futures price causes gold spot prices from Mexico, LBMA, and H&H respectively; NYMEX gold futures price leads gold spot prices from Perth Mint, LBMA and H&H respectively; Merrill Lynch gold index leads estimated gold spot price from Perth Mint and LBMA, H&H respectively; S&P's gold index leads gold spot prices from Perth Mint and H&H respectively. Therefore, these gold futures prices and gold indexes can be interpreted as forecasts of these gold spot prices, which are consistent with finding of studies by Ghosh (1993), Wahab & Lashgari (1993), Tse (1995), Teppo et al (1995), Brooks, et al (2001) and Kavussanos and Nomikos (2003) find that futures prices play an essential role as a predictor of spot prices. According to these findings, producers in Australia, Mexico, US and UK may use gold futures prices of CBOT and NYMEX, gold indexes of Merrill Lynch and S&P's in making production decisions, because these gold futures prices and indexes reflect the gold market’s estimate of the next period’s spot price.

Mexico gold spot price has been found to lead NYMEX gold futures price and gold spot indexes of Merrill Lynch and S&P's, meanwhile, LBMA gold spot price has been found to lead Standard & Poor's gold index by EG’s VECM. However, Johansen’s VECM gives opposite results that fail to reject the hypothesis. Besides, the hypothesis is rejected by Johansen’s VECM estimation on CBOT gold futures price and Perth Mint gold spot price, but the hypothesis is accepted by EG’s VECM. These conflict results, again confirm the interaction relationship cointegrated pairwise gold markets, might be caused by different critical values adopted by Johansen’s and EG’s approaches.

TOCOM gold futures price has been identified to overwhelmingly lead gold spot prices from Perth Mint and LBMA respectively, lead H&H gold spot price with equal power, and the futures price is caused by Mexico gold spot price, by EG’s ECM. Due to absence of long-run equilibrium relationship between TOCOM gold futures price and gold cash markets in Johansen’s cointegration test results, Granger causality test is employed to test possible casualty direction between non-cointegrated gold price series.

The acceptance of the hypothesis that the lagged futures prices and indexes providing an acceptable predictor of the future spot price creates desirable welfare effects. It manifests the economic significance of using futures markets to guide the production of gold because it results in optimal resource allocation in the welfare sense (Stein, 1981). The unbiased futures prices and indexes can remedy the problem of resource misallocation that would exist without futures and index markets and thus help rationalize production decisions and optimal allocation of productive resources (Stein, 1981).

Peck (1985) pointed out that the prediction function may also play at least as an important role as the storage facilitation role for storable commodities. However, there exists no strategy that trader can speculate in the efficient futures market on the future levels of the spot price exploiting profits consistently. Furthermore, it assure the traders that in the event of high fluctuations in the market they can rely upon the direction of the financial markets because they would provide them significant information regarding the prospective move in the spot market. Thus, the investors and institutional traders can design their portfolio and can take positions in the financial market to safeguard themselves from the fluctuations in the cash market. In addition, the regulators will in advance come to know regarding the prospective price movement in the cash market and when they feel market overreacting to the information, they can take appropriate action in the interest of the common investors. Moreover, from the price movements in the futures market they can adjudge the expected volatility in the cash market.

5.6.1 Direction of Causality between Non-Cointegrated Gold Price Series

The causality direction between non-cointegrated pairwise gold prices series is able to be identified by Granger (1969) causality tests. In Granger causality tests, two non-cointegrated prices can be tested whether the previous value of one price predicts current price of the other price. The hypothesis of Granger causality tests that prices do not Granger cause each other can be rejected, if F statistic is significant.

As the result of Granger causality tests shows in Table 5-11, it indicates that the hypothesis of LBMA gold spot price does not Granger cause TOCOM gold futures price is rejected by the significant F statistic; on the other hand, the hypothesis of TOCOM gold futures price does not Granger cause LBMA gold spot price is not rejected, because insignificant F statistic. Therefore, it reveals that the past value of LBMA gold spot price can be used to predict current value of TOCOM gold futures price.

Table 5- 11
Pairwise Granger Causality Tests of Japan Gold Futures Price and UK Gold Spot Price
Sample: 3/24/2000 2/29/2008
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.	Decision
SUK does not Granger Cause FJP^{TOCOM}	2069	318.526***	3E-121	Reject null
FJP^{TOCOM} does not Granger Cause SUK		2.92688	0.0538	Accept null

Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level

The rest of Granger causality tests results are displayed in Table X1-23 at Appendix I. It indicates that TOCOM gold futures price single Granger leads Mexico gold spot price;

meanwhile, gold spot prices from Perth Mint and H&H bidirectional Granger cause TOCOM gold futures price respectively. According to the finding, TOCOM gold futures price is not a good predictor to gold spot prices in the long run.

5.7 Summary of Analysis on Gold Markets

After identified that all the spot prices, futures prices and indexes of gold are integrated of order 1, gold futures prices of NYMEX and CBOT of CME Group are found cointegrated with gold cash markets of Perth Mint, Mexico, LBMA, and H&H, so do gold indexes of S&P and Merrill Lynch. These findings suggest the long-run relationship between gold futures markets and gold cash markets, and between gold index markets and gold cash markets worldwide. It hence suggests that all the tested gold futures contracts and indexes are useful vehicle for reducing overall market price risk faced by cash market participants worldwide.

There is evidence that the price discovery function may work to a certain extent on gold futures and index markets in the long run, as futures price or index adjusts faster and influents greater than that of spot price on the new equilibrium market price, thus achieving better price discovery efficiency in the gold futures and index markets rather than cash market in long-run dynamics.

A precondition for managing risk is that the futures market is able to predict the future spot price at maturity with accuracy (Kumar, 2004). The unbiased predictor hypothesis has been tested by the means of VECM on two cointegrated price series and testing for estimation of the parameters of the cointegrating vector. This mixed evidence is in agreement with studies in other markets, such as, Chowdhury (1991) tests four non-ferrous metals from London Metal Exchange with non-overlapping observation and but found the unbiased predictor of futures price has not been supported; Kolb (1992) finds evidence that silver, platinum, and gold futures prices provide unbiased predictor of expected spot prices. As Fama (1991) suggests that any test of the unbiasedness hypothesis is a joint test that there is no risk premium and that market agents are endowed with rational expectations. Hence, the fail of establishing unbiasedness hypothesis can be attributed to either of evidence for the existence of a risk premium or the result of market irrationality because the market fails to embody in the current futures prices a systematic time series component of the forecast error (Copeland, 1991). The failure implies that the existence of a bias in futures prices increases the cost of hedging, and futures markets do not perform their price discovery role to "discover" future equilibrium prices in spot markets (Kavussanos & Nomikos, 1999). This availability of information regarding future spot prices provides signals that guide supply-and-demand decisions in ways that contribute to a more efficient allocation of economic resources. If futures prices are not unbiased forecasts, then they may not perform their price discovery function efficiently, because they do not represent accurate predictors of expected spot prices.

The short-term deviations from the equilibrium relationship are governed by correction process, thus, the causality tests of the changes in cointegrated price series to be correctly specified by VECM. There is strong evidence of unidirectional or bidirectional (or feedback) causality between two series, and most gold futures prices and indexes dominate or hold greater causality power over gold spot prices. If there is unidirectional causality, gold futures price or gold index dominates the capture of new pieces of information and so leads gold spot price. Thus, gold index can be equally important as sources of information as gold futures prices are in the gold cash markets. Besides, informed traders may choose the one faster at incorporating information as their trading ‘habitat’ to hedge, speculate, or arbitrage; on the other hand, they may choose the slower market—cash markets, informed traders use gold futures prices and indexes to better track future spot price signals and improve their decisions for future trading in gold cash markets. The results are in accordance with the results in most commodity markets, including precious and non-ferrous metals and agricultural markets (see Garbade and Silber (1983) Khoury and Yourougou (1991) Figuerola-Ferretti and Gonzalo (2007), amongst others).

The existence of two-way feedback causal relationship between two markets shows that gold spot price also has impact on short-term price discovery. As Srinivasan and Deo (2009) suggest that it could be due to more investment has been injected into gold markets, in that circumstance, the low transaction cost, minimum margin requirements in futures and index markets encourages the traders to speculate in gold futures and index markets. But investors prefer gold market for liquidity than entering into futures market for hedging or speculation. As a result, gold spot markets helps contribute to price discovery have causality power over futures and index markets.

The feedback relationship would make informed traders to indeed choose a ‘habitat’, as gold cash markets also have impact on predicting subsequent gold spot price. However, as it has been found in prior research, such as, Chan *et al.* (1991) and Pizzi *et al.* (1998), most of gold futures price and indexes lead are found to be stronger than spot prices lead, which implies gold futures and index markets are efficient. Hence, gold producers could reduce their price risk exposure by taking production and marketing decisions on the basis of gold futures and index forecast. Therefore, the hypothesis that gold futures and index market information could reduce gold producers’ price risk can be supported. The conclusions reinforce for policy planners and researchers to track the movements and tendency of gold markets and evolve appropriate mechanisms that allow gold producers to manage their price risk.

EG’s approach has been adopted to support findings of robust Johansen’s approach. Both approaches agree gold futures prices and indexes play the price discovery role in the long-run, sometimes there are different results given by them. EG’s cointegration approach suggests gold futures price of TOCOM cointegrated with all gold spot prices, but Johansen’s approach denied. Granger causality test are taken on these controversial gold price series, but the results are conflicted to EG’s approach suggests, thus, it is hard to make the conclusion that there are long-run or short-term relationship between gold futures price of TOCOM and tested gold spot price, as these results may not be reliable, due to the shortcoming of EG’s approach. On the issue of short-term price dynamics, gold futures prices and indexes are found to have causality power over gold spot price in both approaches, but gold spot prices embody greater causality power in EG’s results than they have in Johansen’s results, and Johansen’s results are closed to the theoretical results.

5.7.1 Economic Interpretation of Results

The results have found that there is a close relationship between US gold index / futures prices and international gold spot prices. The existence of unbiased predictor implies that these futures prices and indexes have the information lead over its overseas counterparts. The empirical evidence suggests the influence of US futures prices / index on international gold spot prices. It also indicates that these futures prices and indexes generally have the information leads in price and hence, and hedgers using them to shift the price risk to others (such as speculators) who are willing and often in a better position to take risks for a possible return (Working 1962).

An efficient price discovery process is characterised by the quick adjustment of market prices from an old equilibrium to a new equilibrium with the arrival of new information. This is underpinned by an efficient system for gathering, processing and disseminating information on the underlying assets. The price discovery process in the US futures and index markets are greatly facilitated by the provision of high quality and timely information on gold.

However, the linkage is not strong enough to suggest a cointegration relationship between futures price in TOCOM and international gold spot prices. This probably reflects the market development level of the TOCOM and restrictions including capital account controls that limit efficient arbitrage activity between Japanese and international markets. The less efficiency of TOCOM may be in connection with its trading volume of precious metal futures contract reduced to less than its trading volume in US futures markets. On the other hand, the efficient and liquid US futures prices and indexes may benefit from early merger and acquisition of futures exchanges and the openness to international markets.

Cross-border futures trading in US futures and index markets increases its overall liquidity of by providing arbitrage opportunities, thus enhancing price discovery at the these markets. The openness of a local exchange to international investors encourages in establishing the exchange as a global price-setting centre for relevant commodities.

Speculators are generally seen to contribute to market liquidity and efficiency by assuming risk on the other side of hedgers' trades and also by assimilating all possible price-sensitive information, on which they can make a profit into the futures market. As majority of gold are stored in bank vaults, the only market participants who may engage in speculative activities are private investors such as small enterprises and individual investors. These investors are generally of small scale, but their investment activities may have great impact on liquidity of gold market. US futures and index markets are well-developed with a diverse investor base. International investors are allowed to participate in US market and speculators in the US market increase the efficiency of price discovery.

5.7.2 Silver

Silver has many shared features with gold that make them similar in many ways. They are both precious metals, used to serve monetary system, and are popular investment targets for many investors. Silver differs in that their value has more rely on production and manufacturing applications and consumer spending; as opposed to gold, which will not tarnish that makes it is commonly produced primarily for accumulation rather than consumption and accepted worldwide as money, and as a means of securing government debts and bonds.

Silver could be considered as a better investment than gold. Because gold is more expensive and valuable than silver, hence it may beyond the reach of most people. Besides, almost all of silver markets having declined during the financial crisis, whilst gold continue to rise steadily in recession and hence, silver is more attractive to the general public. Moreover, the price of silver is also more volatile than gold. The additional amount of currency in circulation, which was required to hold the price of gold constant, also added to the increasing price pressures on silver. To put this into perspective, gold is the only precious metal investment that increased in price every year for the last 10 years. Furthermore, gold is commonly as a store of wealth; silver has more industrial applications than gold, used widely in low-technology as well as high-technology manufacturing, and then silver price is affected more by demand and supply than gold. Therefore, it is interesting to take a look at another precious metal next, which has less power of financial effect nowadays, but take a larger role in manufacture than gold, is silver.

CHAPTER 6

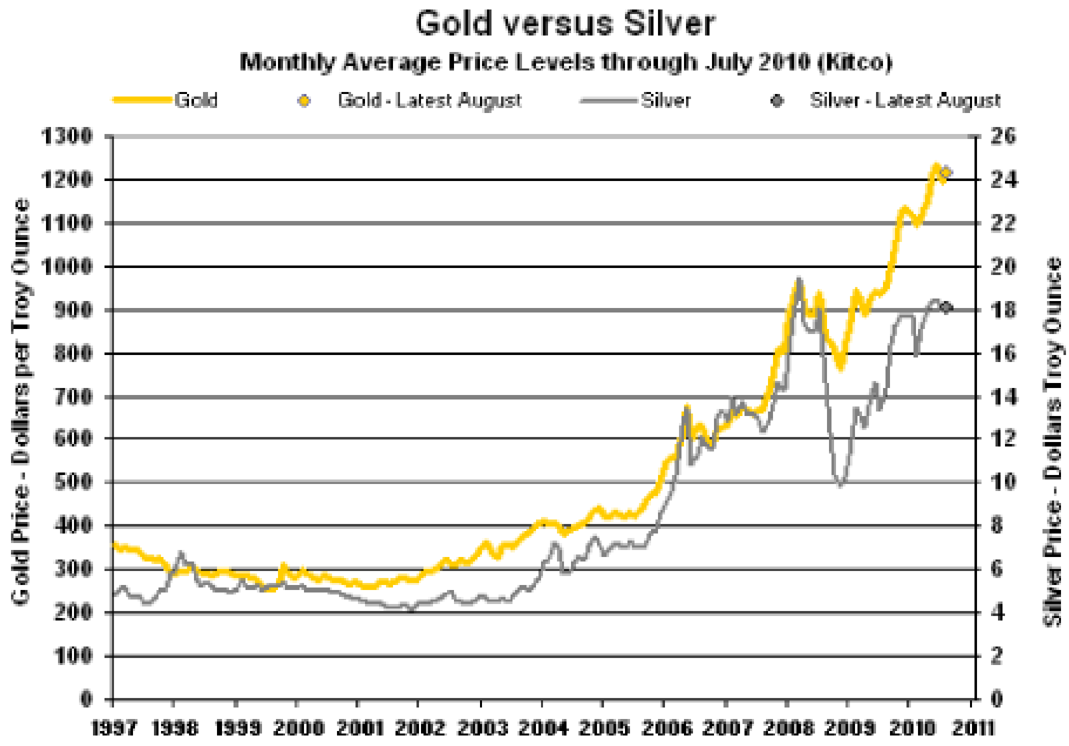
Market Efficiency and Price Discovery in Futures, Spot and Index Markets for Silver

6.1Silver

Gold and silver are valuable for their beauty and rarity. In fact silver has been considered a precious metal and form of real money for nearly as long as gold has. Whilst gold ceased to be used as a form of currency system, silver was used as a direct backing for currency until 1970 in the United States. Thereafter, demand for precious metals has been driven by investors and consumers and industrial use, and prices of precious metals have been extremely volatile, reacting to the interactions of global factors such as inflation, interest rates and various economic and political events (Xu and Fung 2005). The basic arguments for investing in gold apply to silver as well. Precious metals are often used as a hedge against financial stress. Gold has played a critical role in the global economy, and is considered as a safe haven asset and store of value, preserves and protects wealth in times of economic distress, while silver as a precious metal with industrial uses, bridges the gap between gold and industrial metals.

In spite of having many properties like gold, compared to it, silver has lost much of its traditional value since the 1600s onwards; this is due to the discovery of large silver reserves in South America by the Spanish, and most newly mined silver comes from Mexico, Peru, Canada, the US, Australia and Russia. These large reserves made silver less rare than previously believed and less valuable than gold, as silver is nearly 60 times cheaper than gold. Thus, central banks prefer to hold gold rather than silver in their reserves that might be another reason why gold trades with more stability than silver (Kansas2011). However, silver’s lower price makes smaller investors who find gold a bit out of reach easier to buy. As gold has been making one new record high after another, but volatility in bullion is near a five-year low in 2010, which made some investors a less excited in the prospect and led to a record high in sales of silver coins (Farchy 2010). Silver market is smaller in value than gold market, where a large investment can have greater impact on prices in silver market than in gold market. And that makes silver market easily to be manipulated and volatile silver price. As shown in the Figure 6-01, price of silver is volatile compared to gold during last decade.

Figure 6-01 Gold Price and Silver Price



Source: Canadian metal trading company Kitco

Investment is now the biggest single source of demand in gold and gold is already a common holding among hedge funds and some institutions; while silver holdings are still pretty rare, and its consumption is largely accounted for by its wide industrial usage of the later, with commercial uses competing with store of value demands (Evans 2010). The more significant drivers of the silver price have been the increase in investment demand and the producer selling (Dizard 2006). Silver production has been rising steadily in recent years, with most of the growth coming from mines in Mexico, Latin America and Australia. And reserves are limited. According to the U.S. Geological Survey, there are fewer years of U.S. silver production left in the ground than any other precious metal including gold (Cui 2010). On the other hand, as income levels continue to rise in the emerging economies of China, India, and Brazil, an increasing number of consumers are beginning to demand these products as well as viewing silver as an investment. The price of silver has always been the higher beta precious metal, partly because it is not so precious and its demand is much more dependent on industrial application (Dizard 2006). Silver is indispensable to modern society, more than other precious metals, like gold, increasing demand of silver driving by its extensive use for industrial purposes in a number of various fields, such as in the medical and dental fields, imaging and electronics applications, jewellery and solar power that is a source of new demand (Evans 2010). Even price rises cannot bring down the industrial demand for silver as in many cases there are no substitutes for it.

The quickly rising industrial demand for silver results in a highly volatile silver price in recent years, the silver price reached a 22-year high in 2006; and up 30.5% in 2011, the silver price have been achieved its highest level since 1980 (Davis 2006, Flood 2011). Among the four major precious metals-the others being gold, platinum and palladium-silver is up 74% in 2010, on track to be the second-best performing commodity after palladium, which is up 86%, gold, by contrast, is up 26% (Cui 2010). Silver also out performed gold in 2004, 2005 and 2006, however, gold returned to the lead in 2007 (Morgan 2008). The strength in silver prices has prompted a flurry of development around the globe and pushed anticipated production in 2010 to 733.2 million ounces, up 3.3% from 2009 levels, and up 14% since 2006.

Both gold and silver are valued for their rarity, providing coinage for realms both ancient and modern, lending their talents to industrial and scientific uses, investments that are used to reduce certain types of risks in portfolios, particularly high inflation risks. Their prices have benefited from rising political and economic uncertainty, which spurred demand for a safe haven among big and smaller investors respectively[9]. Due to their different personalities, two precious metals have different producing areas, production and consuming volumes, inventories, distinct and important commercial uses for which there are no substitutes, and backers with different demands (Escribano and Granger 1998, Cliner 2001). Thereby, in this chapter, it is of particular interest to explore whether silver's financial markets have fulfilled their function, and whether the performances of silver's underlying financial commodities may vary or similar to gold's.

[9] Gold ends at record, silver recoups losses. (2011). *Wall Street Journal (Online)*

6.2Univariate Stationary Test Results of Silver Price Series

In order to avoid spurious and unreliable results caused by using non-stationary time series, the characteristics and stationarity of each price series is necessary to be assessed. Data transformation is followed if price series is found to be non-stationary; therefore, the results of a regression can be consistent and reliable. The robust Phillips-Perron (PP henceforth) (Phillips and Perron, 1988) nonparametric tests and the Augmented Dickey-Fuller (ADF henceforth) (Dickey and Fuller, 1979) unit root tests are employed in this research to check the stationarity of all the index, futures and spot price series of silver.

The null hypothesis of both ADF and PP unit root tests is all silver price series contain a unit root, against the alternative that all these series are stationary. The null should *not* be rejected if the absolute value of the test statistics is smaller than the absolute value of the corresponding critical value in certain degree significance; otherwise, reject it (Yang and Leatham, 1999, Yang et al., 2001). Both of an intercept and linear time trend were included on both of level and first differences in the tests. Bandwidth in PP tests is by Bartlett kernel, and number of optimal lag in the ADF is selected by Schwarz Information Criteria (SIC) (1978). The source of critical values for rejection of the unit root null hypothesis in both tests is provided by Davidson and Mackinnon (1993). In order to make all series stationary, first differences of the series are taken if null cannot be rejected at level.

The results of the PP and ADF unit root tests on Chicago Board of Trade (CBOT henceforth) silver futures price are presented in Table 6-01 and Table 6-02 respectively, where results for $I(1)$ versus $I(0)$ (level prices) allocate in Panel a, and results for $I(2)$ versus $I(1)$ (first price differences) is in Panels b. In Panels a of Table 6-01 and Table 6-02, it can be seen that the absolute values of computed PP and ADF tests statistics for natural logarithm values of CBOT silver futures price are less than the absolute values of its 10% critical values, thus, the null of unit root is not rejected. It indicates that log-level CBOT silver futures price is non-stationary at the 10% level of significance, and then the PP and ADF tests are performed on the series' first differences.

In logarithmic first differences at Panels b of Table 6-01 and Table 6-02, the absolute values of calculated PP and ADF statistics for CBOT silver futures price are far greater than the absolute values of 1% critical values, and the null of unit root is rejected. The series thus is found to be stationary at 1% significant level or better and the order of integration is said to be one, $I(1)$.

Table 6-01

Phillip-Perron (PP) Unit Root Tests for CBOT Silver Futures Price

$\Delta Y_t = a_1 + \beta_1 Y_{t-1} + \varepsilon_t$

Panel a		Level (lnP)			
Variable	BW	PP Test Statistic	Prob.#	Critical Value at 10%	Stationarity
FUS^{CBOT}	9	-2.624155	0.2695	-3.129619	Non-stationary $I(1)$
Panel b		First difference (ΔlnP)			
Variable	BW	PP Test Statistic	Prob.#	Critical Value at 1%	Stationarity
FUS^{CBOT}	11	-30.62715***	0.0000	-3.437508	Stationary $I(0)$

Note:
All the price series are from March of 2000 to February of 2008
Trend and intercept are added in test at level, apart from only intercept is contained in unit root test of CMXC; and only intercept is added at difference level
BW is the bandwidth chosen by Newey-West automatic truncation lag
#MacKinnon (1996) one-sided p-values.
Asterisks denotes: *** Significant at 1% level; ** Significant at 5% level; * Significant at 10% level

Table 6-02

Augmented Dickey-Fuller (ADF) Unit Root Tests for CBOT Silver Futures Price

$$\Delta Y_t = a_0 + \beta_1 Y_{t-1} + \sum_{t=1}^{n} \beta_t \Delta Y_{t-i} + \varepsilon_t$$

Panel a		Level (lnP)			
Variable	Lag Length	ADF Test Statistic	Prob.#	Critical Value at 10%	Stationarity
FUS^{CBOT}	0	-2.638877	0.2630	-3.129619	Non-stationary $I(1)$
Panel b		First difference (ΔlnP)			
Variable	Lag Length	ADF Test Statistic	Prob.#	Critical Value at 1%	Stationarity
FUS^{CBOT}	0	-46.70879***	0.0001	-3.437508	Stationary $I(0)$

Note:
All the estimated price series are from March of 2000 to February of 2008
Trend and intercept are added in test at level; and only intercept is added at difference level
Optimal lag lengths chosen by Schwarz Info Criterion (SIC)
Asymptotic critical values are from Davidson and Mackinnon (1993)
#MacKinnon (1996) one-sided p-values.
Asterisks denotes: *** Significant at 1% level; ** Significant at 5% level; * Significant at 10% level

The results of testing non-stationarity of all the silver price series, including indexes, futures and spot prices in logarithmic levels and first differences are presented in Tables X2-01 to Table X2-02 in Appendix II. All the silver price series appear to be non-stationary in log-levels at 10% level of significance and stationary in log first differences 1% level of significance based on the reported p-values. It can be concluded that all log-first differenced silver price series are clearly stationary or $I(0)$, thus all log-level silver price series are integrated of the same order or $I(1)$.

Both cointegration (long-run relationship) and lead-lag (short-term causality) relationships are based on the non-stationarity of the time series. Given the results from both PP and ADF unit root tests suggest that all natural logarithm silver price series are integrated of order one, $I(1)$. Thus, it allows testing for the existence of cointegration between pairwise log price series as the logical next step in the empirical analysis.

6.3 Empirical Evidence of H1a: Existence of Long-run Cointegration between Pairwise Silver Markets

The first step to understand relationship between silver futures / silver index and spot markets is to test existence of cointegration between two markets. Cointegration theory suggests that two non-stationary series having same stochastic trend, tend to move together over the long run (Engle and Granger, 1987). However, deviation from long run equilibrium can occur in the short run. The existence of cointegration thus, is the prerequisite of examining market efficiency and price discovery and lead-lag relationship between markets, and the precondition of conducting error correction models.

6.3.1 Determination of the Rank of Cointegration on Silver Price Series (*Bivariate cointegration tests*)

The lag length for Cointegration test and Error Correction Model is selected on minimum value of the Akaike's Information Criterion (AIC) and the Schwarz Criteria (SC). Two information criterions determine up to seven lags length for the regressions in the research. The appropriate lag length proceeds to test cointegration and to whiten the error term for each of the estimations in relation to silver is presented in Tables X2-03 in Appendix II.

6.3.2 Results of Cointegration Tests on Silver Price Series

The silver indexes, futures and spot price have all been found non-stationary, but they become stationary via the first order difference, which indicates they are $I(1)$ variables, thus providing a possibility for the cointegration relationship between the two markets. Two pairwise cointegration approaches, namely Engle and Granger's (1987) (EG's henceforth) and Johansen's (1991, 1995), are employed to examine long-run relationship between two price series. The null hypothesis of both estimations is cointegration relationship between two price series does not exist.

In the EG's (1987) cointegration method, the results of unit root test for residual error from OLS regression of log Tokyo Commodity Exchange (TOCOM henceforth) silver futures price and log Australia Perth Mint (Perth Mint henceforth) silver spot price are shown in Table 6-03. Both ADF and PP test results show clearly null of non-stationary is rejected at 5% and 1% level of significance respectively, which suggests the residual error is stationary, thus the price series of TOCOM futures price and Perth Mint spot price are cointegrated.

Table 6- 03

EG's Cointegration Tests on
Logarithmic TOCOM Silver Futures Price and Logarithmic Australia Perth Mint Silver Spot Prices

ADF test: $\Delta Y_t = a_0 + \beta_1 Y_{t-1} + \sum_{t=1}^{n} \beta_t \Delta Y_{t-i} + \varepsilon_t$ PP test: $\Delta Y_t = a_1 + \beta_1 Y_{t-1} + \varepsilon_t$

Variables	ADF Test	PP Test	H_0: $I(1)$	Conclusion
FJP and SAU	-3.033096***	-3.538419***	rejected	Cointegrated

Notes:
*** Statistically significant at 1% level; ** Statistically significant at 5% level

The EG's cointegration results of all the pairwise log silver price series, presented in Table X2-04 to Table X2-08 in Appendix II, show residual error from every OLS regression is stationary, and thus there is the cointegration relationship between silver futures and spot prices, and between silver index and silver spot price, given by EG's methods.

Johansen's (1991, 1995) two likelihood ratio tests are used to test the long-run relationship as well. The results of Johansen cointegration test on TOCOM silver futures price and Perth Mint silver spot price are shown in Table 6-04. As we can see, the null hypothesis that no cointegrating vector exists cannot be rejected at the 5% significant level in both of the trace and the max eigenvalue tests. In this case, there is no cointegration equation, which means TOCOM silver futures price and Perth Mint silver spot price are not cointegrated.

Table 6- 44

Johansen's Cointegration Tests on
Logarithmic TOCOM Silver Futures Price and Logarithmic Australia Perth Mint Silver Spot Prices

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^{p} \ln(1-\tilde{\lambda_i})$$

Price Variables	H_0: rank=r	H_1: rank=r	λ_{trace} Statistics	Critical Values	Conclusion
FJP and SAU	r ≤ 0	r > 0	16.17790	25.87211	Non-Cointegrated
	r ≤ 1	r > 1	6.477311	12.51798	Non-Cointegrated

$$\lambda_{Maximal\ Eigenvalue}(r, r+1) = -T \ln(1-\widetilde{\lambda_{r+1}})$$

Price Variables	H_0: rank=r	H_1: rank=r	λ_{max} Statistics	Critical Values	Conclusion
FJP and SAU	r = 0	r = 1	9.700585	19.38704	Non-Cointegrated
	r = 1	r = 2	6.477311	12.51798	Non-Cointegrated

Notes:
r is the number of cointegrating vectors
* denotes rejection of the hypothesis at the 0.05 level
Critical Value is at 5% significant

The results of Johansen cointegration tests on the US silver financial prices and silver spot price, presented in Table X2-09 to Table X2-12 in Appendix II, show the null hypothesis of one cointegrating vector exists can be rejected at 5% level of significance. It implies that US silver futures price (of either New York Mercantile Exchange or Chicago Board of Trade) is cointegrated with (any of concerned) silver spot price; US index (of either S&P or Merrill Lynch) is cointegrated with (any of concerned) silver spot price. On the other hand, the null hypothesis of one cointegrating vector exists cannot be rejected at 5% level of significance shown in Table X2-13 in Appendix II, which suggests that Japan TOCOM silver futures price is independent to most of tested silver spot prices, with exception of TOCOM silver futures price and Mexico silver spot price.

As what has been found in gold market, the conflicting results of EG's and Johansen's cointegration tests on TOCOM futures price and other spot prices appear in silver markets as well. Johansen's results suggest that TOCOM silver futures price is independent to worldwide silver spot prices and TOCOM is not efficient in holding the information on the price change in these silver markets. Its capability on silver futures contract in TOCOM could be limited by its liquidity and information in international trading. This problem may reflect the openness of TOCOM and Japanese financial markets to international market practitioners.

In summary, opposite conclusions on cointegration on TOCOM silver futures price and prices from tested spatial silver cash markets has been given by EG's and Johansen's cointegration tests. The absence of cointegration could mean the violation of the necessary condition for the simple efficiency hypothesis and error correction model. It implies that TOCOM silver futures price is not an unbiased predictor of the spot price at maturity, and long-run and short-term price dynamics of TOCOM silver futures price are unable to examine under Johansen's approach. Moreover, the same decision given by both EG's and Johansen's cointegration tests is: the null hypothesis that cointegration does not exist is rejected and US silver futures prices (from New York Mercantile Exchange or Chicago Board of Trade) are cointegrated with the world cash markets, and US silver indexes (from Standard & Poor's or Merrill Lynch) are cointegrated with the world cash markets. The results of existence of cointegration in silver markets are as the same as the results have been found out in gold markets.

Once the cointegration relations were identified, error correction terms were extracted in a bivariate VAR system to constitute a VEC model in first differences. This enabled the examination of market efficiency that futures price and index could use to predict future spot price, and examination of casual relationships through which any long-run information about the dynamics of the cointegrated price series can be exposed, while preserving the short-run casual effects on the behaviour of the dependent price series.

6.4 Empirical Evidence of H2a: Unbiased Predictor of Silver Future Spot Prices

Data that has been testified to be stationary and cointegrated using EG and Johansen tests, can be used to test the unbiasedness hypothesis that the futures price and index are the unbiased predictors of future spot price by using Johansen's Vector Error Correction Model (VECM henceforth).

A restriction is imposed into VECM respect to the cointegrating parameters to be (1, -1), the null hypothesis that financial price is an unbiased predictor of spot price is rejected if computed statistics of Chi-square is significant. Optimal lag length put into VECM is selected by both Schwarz Information Criteria (SIC) and Akaike's Information Criterion (AIC). The empirical results show supporting evidence of cointegration among the series considered in all markets, apart from TOCOM silver futures price. These cointegrated non-stationary silver price series are consistent with a necessary condition for the efficient market hypothesis.

The estimated results on unbiasedness of pairwise cointegrated non-stationary silver price series are presented in Table 6-11 below. The empirical evidence suggests that some financial markets, aiding the process of price discovery, are efficient and unbiased in the long-run. These markets are Chicago Board of Trade (CBOT henceforth) silver futures price provides useful information on future movements of silver spot prices at US Handy & Harman (H&H henceforth) (the same as gold markets); NYMEX silver futures market is efficient, and plays an important role in price discovery of future silver spot prices at UK London Bullion Market Association (LBMA henceforth) and US H&H (the same as gold markets); Standard & Poor's (S&P henceforth) silver index is efficient, and the current Standard & Poor's silver index has the predictive power for the future silver spot price of LBMA. These results confirm that these silver futures prices and index have performed this fundamental economic function well.

Table 6- 05 Parameter Restriction on Silver Markets

Silver Markets	Chi-square (1)	Probability	Unbiased Predictor of Spot Price
CBOT silver futures price and Australia silver spot price	4.735040**	0.029554	No
CBOT silver futures price and Mexico silver spot price	47.29660***	0.000000	No
CBOT silver futures price and US silver spot price	2.270033	0.131897	Yes
CBOT silver futures price and UK silver spot price	6.174984**	0.012957	No
NYMEX silver futures price and Australia silver spot price	1.090602	0.296338	Yes
NYMEX silver futures price and Mexico silver spot price	19.02926***	0.000013	No
NYMEX silver futures price and US silver spot price	58.08177***	0.000000	No
NYMEX silver futures price and UK silver spot price	0.413798	0.520048	Yes
Japan silver futures price and Mexico silver spot price	11.52302***	0.000687	No
Merrill Lynch’s silver index and Australia silver spot price	8.722045***	0.003144	No
Merrill Lynch’s silver index and Mexico silver spot price	18.03462***	0.000022	No
Merrill Lynch’s silver index and US silver spot price	37.25103***	0.000000	No
Merrill Lynch’s silver index and UK silver spot price	6.402670**	0.011395	No
S&P’s silver index and Australia silver spot price	6.722724***	0.009519	No
S&P’s silver index and Mexico silver spot price	17.07282***	0.000036	No
S&P’s silver index and US silver spot price	38.50392***	0.000000	No
S&P’s silver index and UK silver spot price	3.007136	0.082899	Yes

Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level;

Comparing with the results found in gold market, fewer futures prices and indexes appear to be unbiased predictors of future spot prices in international silver markets. Most of silver futures and index prices failed to provide efficient information for market participants to capture accurate future change in spot silver prices. It could be caused by the dual financial and industrial character of silver. Whereas the major role of gold is on finance, the price of silver is affected by its industrial demand as well. Moreover, although these silver financial prices are not an unbiased predictor, they are linked to the silver spot prices in the long run as we found earlier. Therefore, these financial prices are useful to silver investors if further short-term price relationship between them and silver spot prices is revealed.

6.5 Empirical Evidence of H3a: Price Discovery Role of Silver Futures Prices or Indexes

If a co-integrating relationship between two $I(1)$ price series is discovered, an error correction model exists (Granger 1986 and Engle and Granger 1987). The error correction model can be interpreted as showing the existence of a long-run equilibrium relationship between two price series, but in the short run, however, there may be disequilibrium. With the error correction mechanism, a proportional disequilibrium in one period is corrected in the next period. VECM, thus, is used to identify which price series play the main role of discovering the price in next period. The a_1 and a_2 in Johansen (1988a)'s VECM equations (equation 4.19 and equation 4.20) are the speed of adjustment parameters that is to measure the speed with which deviations from the long-run relationship are corrected by changes in the spot and futures prices. The larger absolute form of significant a represents the higher level of adjustment and greater response of the series to deviations from long-run equilibrium and the price gap between the series will be very stable.

The optimal lags in VECM are selected by the minimization of the Akaike information criterion; minimization of the Schwarz Bayesian information criterion is also employed to select alternative lags and double-check the robustness of the empirical findings. As shown in Table 6-06 below, coefficients statistics of adjustment parameters a are significant at 1% level in both futures and spot prices equations, which show a sustainable long-term equilibrium is attained by closing the gap between CBOT silver futures price and Australia's silver spot price. No clear long run equilibrium relationship to identify leadership in price discovery between these two markets; however, the absolute value of a_2 from spot price equation is greater than the absolute value of a_1 from futures price equation show CBOT silver futures price makes greater contribution to price discovery.

Table 6-06

Johansen's Error correction model on
logarithmic US CBOT silver futures price and logarithmic Australia spot price

FUS_t^{CBOT}	Coefficient	Standard Error	t-Statistics	SAU_t	Coefficient	Standard Error	t-Statistics
β_1	1			β_2	-0.996801***	0.00145	-687.295
μ_1	0.000968	0.00068	1.42206	μ_2	0.000935***	0.00032	2.92343
a_1	-0.356104***	0.14116	-2.52268	a_2	0.552025***	0.06636	8.31926
ρ_{111}	0.297442**	0.13649	2.17916	ρ_{211}	0.354516***	0.06416	5.52539
ρ_{112}	0.303529**	0.12819	2.36772	ρ_{212}	0.191997***	0.06026	3.18615
ρ_{113}	0.356963***	0.11497	3.10487	ρ_{213}	0.141332***	0.05404	2.61517
ρ_{114}	0.192959*	0.09992	1.93123	ρ_{214}	0.155833***	0.04697	3.31793
ρ_{115}	0.027352	0.07629	0.35851	ρ_{215}	0.019774	0.03586	0.55136
ρ_{121}	-0.246970*	0.13400	-1.84301	ρ_{221}	-0.219685***	0.06299	-3.48759
ρ_{122}	-0.361597***	0.11928	-3.03143	ρ_{222}	-0.202543***	0.05607	-3.61227
ρ_{123}	-0.257939***	0.10595	-2.43443	ρ_{223}	-0.181164***	0.04981	-3.63741
ρ_{124}	-0.021195	0.08642	-0.24526	ρ_{224}	-0.020808	0.04062	-0.51221
ρ_{125}	-0.089484**	0.03934	-2.27447	ρ_{225}	-0.025173	0.01849	-1.36116
R^2	S.D. dependent	S.E. equation	F-statistic	R^2	S.D. dependent	S.E. equation	F-statistic
0.026769	0.019829	0.019685	2.175439	0.750214	0.018399	0.009253	237.5437

Notes

In the estimated ECM results, β_1 and β_2 cointegration parameters, μ_1 and μ_2 are intercepts, a_1 and a_2 are coefficients for the Error correction term, ρ_{11i} is the coefficient for ΔFUS_t^{CBOT} at lag i in the ΔFUS_t^{CBOT} equation, ρ_{12i} is the coefficient for ΔSAU_t at lag i in the ΔFUS_t^{CBOT} equation, ρ_{21i} is the coefficient for ΔSAU_t at lag i in the ΔFUS_t^{CBOT}equation, ρ_{22i} is the coefficient for ΔSAU_t at lag i in the ΔSAU_t equation

Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level; * Statistically significant at 10% level

The adequacy of the model is checked by analysing the standardized residuals. After standardising there should be no autocorrelation in the residuals and squared residuals, if the model is well specified. This diagnostic check is performed by analysing the Lagrange multiplier (LM) tests of the series. The lag lengths chosen to whiten the error term and as tests for autocorrelation LM tests for the presence of autocorrelation up to the 12th order are reported in Table 6-07, and the p-values of the LM test are shown that no problems with autocorrelated residuals occur.

Table 6-07

VEC Residual Serial Correlation LM Tests
Null Hypothesis: no serial correlation at lag order h
Sample: 3/24/2000 2/29/2008
Included observations: 882

Lags	LM-Stat	Prob	Lags	LM-Stat	Prob
1	7.629459	0.1061	7	1.450093	0.8354
2	9.620962	0.0473	8	7.107842	0.1303
3	6.965669	0.1377	9	16.24425	0.0027
4	4.870765	0.3008	10	10.04567	0.0397
5	5.280063	0.2597	11	10.24469	0.0365
6	2.938705	0.5681	12	7.395118	0.1164

Probs from chi-square with 4 df.

The EG's bivariate VECM is based on the traditional EG's cointegration method. Although Johansen's method is considered robust, using EG's VECM in this research is to support Johansen's results. In EG's bivariate VECM, the residuals from price series have been embed in a VECM in order to gauge short- and long-run Granger causality which allows formal classification of lead/lag behaviour. The lag length of the EG's VECM is chosen on basis of the Akaike information criterion and Schwarz Bayesian information criterion. The adjustment parameters a_1 and a_2 in EG's bivariate VECM describe the price' ability to maintain the long-run equilibrium and imply their price discovery function. The greater coefficients of significant adjustment parameters, the stronger price discovery power of these prices.

The EG's VECM estimation results on CBOT silver futures price and Australia's silver spot price displayed in Table 6-08 show the statistical significance and absolute values of adjustment parameters a_1 and a_2 in futures and spot prices equations respectively indicate both CBOT silver futures price and Perth Mint silver spot price contribute to price discovery, but Perth Mint silver spot makes slightly greater effort on resuming equilibrium. The p-values of the LM test in Table 6-09 show a presence of weak serial correlation in residuals, which indicates the residuals appear reasonable well behaved.

Table 6-08

EG's Vector Error Correction Model on logarithmic US CBOT silver futures price and logarithmic Australia silver spot price

$\mathrm{FUS}_t^{\mathrm{CBOT}}$	Coefficient	Standard Error	t-Statistics	SAU_t	Coefficient	Standard Error	t-Statistics
β_1	1			β_2	-0.996864***	3.3E-07	-2996714
μ_1	0.000954***	0.00032	2.98989	μ_2	0.000935***	0.00032	2.92131
a_1	-0.450375***	0.06620	-6.80336	a_2	0.551341***	0.06641	8.30228
ρ_{111}	0.353784***	0.06400	5.52808	ρ_{211}	0.354914***	0.06420	5.52825
ρ_{112}	0.190527***	0.06013	3.16839	ρ_{212}	0.191135***	0.06032	3.16848
ρ_{113}	0.139237***	0.05404	2.57649	ρ_{213}	0.139687***	0.05421	2.57667
ρ_{114}	0.155060***	0.04685	3.30995	ρ_{214}	0.155531***	0.04699	3.30952
ρ_{115}	0.019653	0.03577	0.54946	ρ_{215}	0.019707	0.03588	0.54925
ρ_{121}	-0.218734***	0.06283	-3.48150	ρ_{221}	-0.219423***	0.06303	-3.48145
ρ_{122}	-0.200639***	0.05600	-3.58290	ρ_{222}	-0.201290***	0.05618	-3.58318
ρ_{123}	-0.179985***	0.04969	-3.62181	ρ_{223}	-0.180535***	0.04985	-3.62142
ρ_{124}	-0.020716	0.04052	-0.51130	ρ_{224}	-0.020765	0.04064	-0.51091
ρ_{125}	-0.024587	0.01848	-1.33035	ρ_{225}	-0.024662	0.01854	-1.33020
R^2	S.D. dependent	S.E. equation	F-statistic	R^2	S.D. dependent	S.E. equation	F-statistic
0.786350	0.019829	0.009229	266.5331	0.750264	0.018399	0.009258	217.5563

Notes

In the estimated ECM results, β_1 and β_2 cointegration parameters, μ_1 and μ_2 are intercepts, a_1 and a_2 are coefficients for the Error correction term, ρ_{11i} is the coefficient for $\Delta\mathrm{FUS}_t^{\mathrm{CBOT}}$ at lag i in the $\Delta\mathrm{FUS}_t^{\mathrm{CBOT}}$ equation, ρ_{12i} is the coefficient for $\Delta\mathrm{SAU}_t$ at lag i in the $\Delta\mathrm{FUS}_t^{\mathrm{CBOT}}$ equation, ρ_{21i} is the coefficient for $\Delta\mathrm{SAU}_t$ at lag i in the $\Delta\mathrm{FUS}_t^{\mathrm{CBOT}}$equation, ρ_{22i} is the coefficient for $\Delta\mathrm{SAU}_t$ at lag i in the $\Delta\mathrm{SAU}_t$ equation Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level; * Statistically significant at 10% level

Table 6-09
VEC Residual Serial Correlation LM Tests
Null Hypothesis: no serial correlation at lag order h
Sample: 3/24/2000 2/29/2008
Included observations: 882

Lags	LM-Stat	Prob	Lags	LM-Stat	Prob
1	9.977335	0.0408	7	4.680004	0.3217
2	1.171857	0.8827	8	4.158917	0.3849
3	3.247039	0.5174	9	7.114049	0.1300
4	8.078127	0.0888	10	4.354044	0.3602
5	4.782843	0.3103	11	4.846937	0.3034
6	3.461105	0.4838	12	1.053529	0.9016

Probs from chi-square with 4 df.

According to the EG's and Johansen's VECM estimations in relation to silver price series in Table X2-14 to Table X2-22 in Appendix II, both types of VEC estimations support that CBOT silver futures price is the main contributor to price discovery rather than Perth Mint silver spot price and LBMA silver spot price; and CBOT silver futures price leads H&H and Mexico silver spot prices respectively in price discovery. NYMEX silver futures price is the main contributor to price discovery rather than any tested silver spot price. Merrill Lynch silver index is the main contributor to price discovery rather than silver spot prices of Perth Mint, Mexico and LBMA; and Merrill Lynch silver index leads H&H silver spot price. And S&P silver index is the main contributor to price discovery rather than any tested silver spot price.

As Johansen's VECM on TOCOM silver futures price cannot be carried out due to absence of cointegration in previous step, EG's VEC estimations suggest that silver futures price of TOCOM is the main contributor to price discovery than silver spot prices from Perth Mint, Mexico, LBMA and H&H. Finally, a diagnosis check is conducted on the residuals from the aforementioned VEC estimations ensure that the residuals of Johansen's and EG's estimations are not autocorrelated.

Similar with what has been found in gold markets, silver futures prices and indexes have a greater speed of adjustment to the previous period's deviation from long-run equilibrium than the silver spot price series has been discovered in all the EG's and Johansen's VECM results. Therefore, the hypothesis that futures prices and indexes are the primary informational sources of spot prices during 2000 to 2008 fails to be rejected for silver. It suggests that price change in silver futures and silver index markets lead price changes in silver cash markets more frequently than the opposite in the long run, while the price discovery function may work to a certain extent on silver cash markets during estimated period. Besides, the influence of the change of silver futures price or silver index is greater than that of silver spot price on the market price, which reflects the importance of silver futures markets of CBOT, NYMEX, and TOCOM, and silver index markets of S&P's and Merrill Lynch's, to stabilize the market price, and these silver futures and index markets are efficient.

6.6 Empirical Evidence of H4a: Short-term Causality of Silver Price Series

Silver futures and index markets have been found to be cointegrated with worldwide cash markets. It may be possible that prices are cointegrated in the long run but deviate in the short run. Hence, whether there is any lead-lag relationship between these silver financial markets and spot prices of worldwide silver cash markets need to be further investigated.

If a co-integration relationship between two $I(1)$ price series is discovered, an error correction model should include residuals from the vectors, the last period's equilibrium error, as well as the lagged values of the first differences of the variable in a dynamicVECM. Thus, temporal causality can be assessed by examining the statistical significance of parameter ρ, relative magnitudes of error correction coefficients and coefficients on the lagged variable.

As result of Johansen's VECM estimation on CBOT silver futures price and Perth Mint silver spot price shown in the Table 6-06, with the lag length decided by Akaike information criterion and Schwarz Bayesian information criterion. The statistically significant coefficients of lags ρ_{11i} and ρ_{12i} in first differences CBOT silver futures price equation show the past move of Perth Mint silver spot price and CBOT silver futures price has impact on current move of CBOT silver futures price respectively; coefficients of ρ_{21i} and ρ_{22i} in first differences Perth Mint silver spot price equation are statistically significant states the past move of CBOT silver futures price and Perth Mint silver spot price has impact on current move of Perth Mint silver spot price respectively. These number and figures of statistic significant lags ρ indicate that Perth Mint silver spot price and CBOT silver futures price cause each other with similar causality power based on bidirectional causality relationship.

As EG's VECM estimation on CBOT silver futures price and Perth Mint silver spot price shown in the Table 6-08, with the lag length decided by Akaike information criterion and

Schwarz Bayesian information criterion. The statistically significant coefficients of lags ρ in both equations show past move of Perth Mint silver spot price has impact on current move of itself and CBOT silver futures price; and the past move of CBOT silver futures price has impact on current move of itself and Australia's silver spot price. These figures of lags ρ indicate CBOT silver futures price has greater causality power over Perth Mint silver spot price based on their bidirectional causality relationship.

Therefore, bidirectional causality relationship between CBOT silver futures price and Australia Perth Mint silver spot price has been verified by both Johansen's and EG's VECMs. And this feedback relationship has also been found in gold prices between Chicago Board of Trade futures price and Perth Mint spot price. The results of all the Johansen's and EG's VECM applied on cointegrated silver price series are displayed in Table X2-14 to Table X2-22 in Appendix II. The hypothesis that silver futures and index markets lead silver cash market cannot be rejected in following markets, based on either unidirectional or bidirectional causality relationship, confirmed by both VECM approaches.

With a unidirectional causality relationship, CBOT silver futures price leads Mexico silver spot price, NYMEX silver futures price leads silver spot prices from Mexico and H&H respectively, Merrill Lynch silver index leads silver spot prices from H&H and Mexico respectively, S&P silver index leads silver spot prices from Mexico and H&H respectively, and TOCOM silver futures price leads Mexico silver spot price, but not vice versa.

Based on a bidirectional causality relationship, CBOT silver futures price is caused by LBMA silver spot price, NYMEX silver futures price has stronger impact on silver spot prices from Perth Mint and LBMA respectively, Merrill Lynch silver index has more impact on Perth Mint and LBMA silver spot prices respectively, S&P silver index has stronger impact on silver spot prices from Perth Mint and LBMA respectively. Based on a bidirectional causality relationship with a similar impact over each other, there are CBOT silver futures price and H&H silver spot price, CBOT silver futures price and Perth Mint silver spot price.

The above results suggest that silver futures prices and indexes fulfil their price discovery role and lead silver spot prices in most of cases. In virtue of the predictive power of these silver futures prices and indexes, silver commercial (hedgers) traders like producers, manufacturers and commercial dealers, are able to make optimal decisions in hedging, production and development plans, and international silver investors gain more opportunities to make profits from their investment activities in international markets.

As the absence of long-run equilibrium relationship between Japan TOCOM silver futures market and silver cash markets from Australia, US and UK by Johansen's cointegration test. Unidirectional causality relationships have been observed by EG's ECM and Granger causality tests regarding to Japan Tokyo Commodity Exchange silver futures market and silver spot prices from Australia, US and UK respectively. Silver spot prices from Perth Mint, LBMA and H&H have been found to have a greater impact on TOCOM silver futures price via both EG's ECM and Granger causality estimations. These results confirm that price discovery happened in silver spot, futures and index markets, as has been found by Johansen's VECM. But the predictive power of silver spot prices has been enlarged in EG's ECM and Granger causality tests, it may be caused by critical values used in EG's VECM.

6.6.1 Direction of Causality between Non-Cointegrated Silver Price Series

The causality direction between not cointegrating pairwise silver prices series may be identified by Granger causality tests. The previous value of one price can predict the current price of the other series, even if they are not cointegrated. The hypothesis of Granger causality tests that one price does not Granger cause the other price can be rejected, if the F statistic is significant. As the result of Granger causality tests shows in Table 6-10, it indicates that the hypothesis that the LBMA silver spot price does not Granger cause the TOCOM silver futures price is rejected by the significant F statistic; on the other hand, the hypothesis of TOCOM silver futures price does not Granger cause LBMA silver spot price is not rejected, because of insignificant F statistic. Therefore, it reveals that the past value of LBMA silver spot price can be used to predict current value of TOCOM silver futures price.

Table 6- 10

Pairwise Granger Causality Tests of Japan Silver Futures Price and UK Silver Spot Price
Sample: 3/24/2000 2/29/2008
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
SUK does not Granger Cause FJP^{TOCOM}	2069	428.706***	2E-156
FJP^{TOCOM} does not Granger Cause SUK		0.71181	0.4909

Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level

The rest results of Granger causality tests are displayed in Table X2-23 at Appendix II. It indicates that silver spot prices from Perth Mint and H&H Granger cause TOCOM silver futures price respectively, but not vice versa. Meanwhile, TOCOM silver futures price leads Mexico silver spot price based on bidirectional relationship. According to the finding, TOCOM silver futures price is not a good predictor to silver spot prices in the long run.

6.7 Summary of Analysis on Silver Markets

Applied to the data of silver, the results suggest pairwise price series—US silver futures and spot prices, US silver index and spot price that form a cointegrated system and, are linked by a long-run equilibrium relationship. Meanwhile, it has found that silver futures and index markets are the primary source of long-run price discovery in most of cases. These results are consistent with the findings in gold markets.

Fewer silver futures and index markets are found to be unbiased and hence efficient for current silver spot prices compare to the result in gold market. It could be due to market participants choose physical silver markets as their trading ‘habitat’, as silver has industrial demand by manufacturers and refiners; besides, its lower price attracts investment in silver market serves smaller trading quantity to smaller participants who could not afford to invest in gold, and also its large reserves. It could be a consequence of efficient transmission of information among traders in silver cash market leads silver to be traded more frequently and increase its markets liquidity. As we know silver market is small and the increasing trading in cash markets could result in its volatile price, this fact could have attracted investors’ interests to hedge, speculate, or arbitrage in its futures. Therefore, in test of short term dynamics causality, unidirectional causality is found to be running form silver futures and index market to silver spot market, and feedback causality has been found more extensively in silver than gold markets. Even the results show almost of all silver futures and index markets with feedback relation to cash markets appear to be greater lead and have the predicting power to future spot price, there are more silver cash markets help contribution to consequent spot price and reduce overall market price risk faced by cash market participants worldwide than cash markets found in gold market.

6.7.1 Economic Interpretation of Results

The temporal relationship between futures price / index and spot price implies market efficiency and arbitrage. Tests on speed of adjustment suggest silver futures / index and spot markets act as a means of price discovery in world silver markets, improving information in markets, and allowing them to settle on equilibrium prices more rapidly. There is evidence to suggest that few US silver futures price / index markets are efficient, and the futures price / index are unbiased predictors of spot price in the next period. Hence, these efficient futures / index markets are a useful hedging mechanism for the underlying spot market. This means that industrial and other market participants have an alternate means of hedging beyond the physical holding of the metal. Meanwhile, no risk-free return and no information on profitable arbitrage opportunities are given to investors (Dwyer and Wallace 1992). There is no difference to investors to buy silver and hold it, or to buy silver later at the previously contracted futures price. Because the silver futures price is similar to the current silver price, thereby incurring the storage costs. Thus, that the previous periods' US futures / index prices is found as an unbiased predictor of expected current silver spot price implies that there was no risk premium in the market and there was long-run market efficiency, thereby reducing the amount of arbitrage to minimum.

The existence of cointegration indicates the link between US silver futures / index market and silver spot market worldwide. If futures market is efficient, futures are a useful hedging mechanism for the underlying spot market. This means that industrial and other market participants have an alternate means of hedging beyond the physical holding of the metal. Arbitrageurs and speculator are interested in making a profit, and will only enter the contract if they expect to make money. As most of the US silver futures / index markets in this research have been found to be inefficient, the arbitrage opportunities exist. Arbitrageurs transmit information into these silver futures / index and spot markets by taking advantage of risk free profitable opportunities between these silver futures / index and spot markets. The relative mispricing across the silver futures / index and spot markets can be reduced or removed by these arbitrage activities. Therefore, a linkage between spot market and the futures market can be maintained by arbitrageurs.

The short-run dynamics also indicate silver futures / index prices contain information of future movements of silver prices, investors can use this information with future price prediction. In this regard, governments may motivate and inform the hedgers using the silver futures / index markets as the optional choice on reducing or protecting the risk in the future price fluctuation. Therefore, for the benefits of market participants and maintain market stability, it is important to update these market performance and their relationships under the dynamic economy. Moreover, non-commercial (speculative) traders like hedge or speculators might set up a fund for trading, and their speculative behaviours may eventually drive the futures price to equal the future spot price. Therefore, the government may support the setting up the funds to make the futures market efficiency and to develop the potential of agents in the futures market.

6.7.2 Platinum

Apart from the best-know precious metal gold and silver, there are several characteristics of platinum that attract investors' interests. Although platinum does not have the same currency characteristics as gold and silver have, it could regain favour as a result of heavily use in the automobile industry, and a revitalization of the platinum jewellery trade. Platinum's essential use in the automotive. Today, this metal is still vital to that industry, but has grown in acceptance as investor's metals and has also become useful for a broader range of manufacturing processes.

Platinum is one of the rarest of the precious metals and its price is more valuable than gold. The value of platinum has increased significantly in recent years, because of their essential industrial usage and scarcity. The price of platinum sometimes surges to very high levels, as its spot price reached a record high of $2,229 an ounce in March of 2008, caused by a net supply deficit of 480,000 troy ounces of platinum in 2007 (Maylie, 2008). Its output is recovering in the largest producing nation, South Africa, which mined 70% of world platinum in 2007. Platinum is in great industrial demand, as its new uses as technology advances for various manufacturing processes have been discovered consistently. While investors have typically purchased gold or silver when making an investment on precious metals, platinum offers investors the opportunity to diversify their precious metals holdings.

Chapter 7

Market Efficiency and Price Discovery in Futures, Spot and Index Markets of Platinum

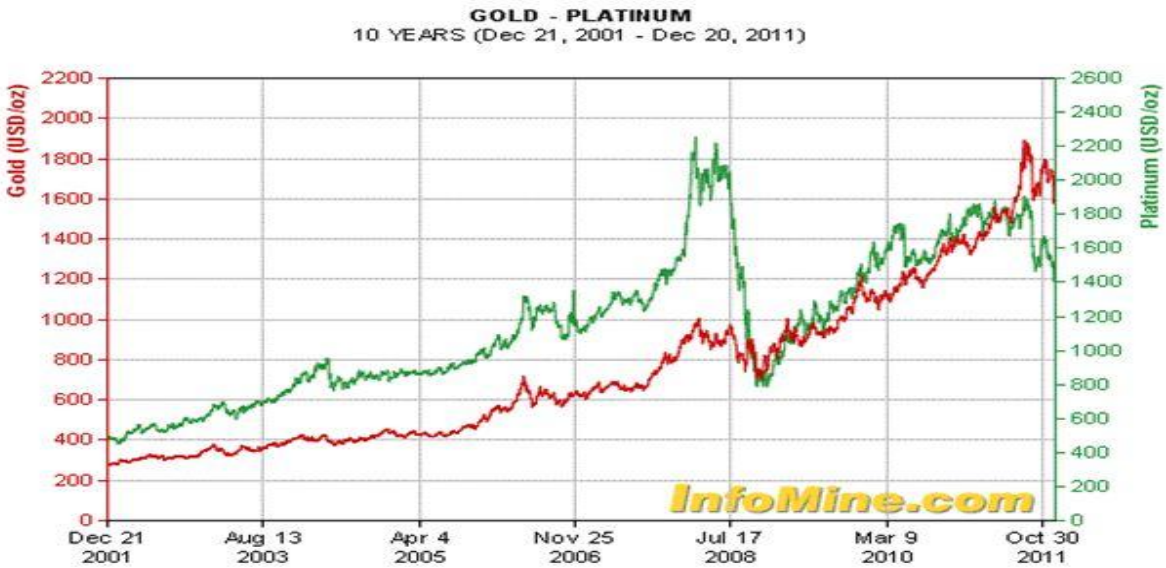
7.1 Platinum

Deposits of gold and silver have been found around the globe for thousands of years. By contrast, platinum mining is relatively new. Platinum is an elite, expensive metal, with the highest resistance to corrosion and tarnish, and will never chip or splinter. Platinum is precious not only because of its beauty, durability, pliability and density, but because of its rarity. It is 30- times rarer than gold since the beginning of 1990 and costs twice as much, which is attributable to the fact that it takes more than 14 tonnes of rock to produce a single ounce of platinum and between three and six months for the myriad chemical processes to be completed that enable a polished platinum ingot to emerge (de Burton, 2007, Edwin, 2011). The world's most important diamonds are set in platinum because of its hardness and durability (Besler, 2010). The annual supply of platinum is only about 130 tonnes, which is equivalent to 6% (by weight) of the total western world's annual mine production of gold and less than 1% of silver's yearly mine production. About 90% of known platinum reserves and 60%-70% of global platinum supply are located in South Africa. Any turmoil, political or labour, in South Africa can therefore affect supply and prices.

Few short decades ago, platinum was seen more of an industrial metal than a precious one, because most of its demand came from auto-catalyst makers and its price had direct correlation with economic expansion. Platinum is still largely used in industrial processes and required in many valuable industrial applications, such as vehicle catalytic converters which accounts for almost half of demand. However, in recent years the metal has been extensively used in jewellery, which took just about 31% of its production in 2010 (Denning, 2011, Edwin, 2011). The rise of emerging economies increased the demand for luxury goods and; China, as an example, has became the most important jewellery market for platinum and now accounts for about half of global platinum consumption with Japan, the US and Europe following behind in 2000 (Morrison and Tett, 2004). As all central banks, particularly in the emerging nations, hold vast quantities of gold as one of the components of its reserves, platinum is not known to be held by any central bank, its availability is too small to become a reserve holding.

The smaller market size of platinum makes its price more volatile than gold and so less reliable as a store of value, as demonstrated in Figure 7-01 below. Investors can either choose physical or non-physical platinum market to invest as they do in gold and silver markets. Platinum coins or bars are available at Perth mint in Australia for investors who want to own the physical metal; however, for large investment amounts, it would be quite impractical and risky to own physical platinum as transportation and storage becomes an issue. In this case, non-physical would be a more convenient, safer alternative. Derivatives, like options or futures contracts, offer leverage to the platinum investors to take up a position by buying platinum options or futures contracts, allow them to control a large position in platinum for a relatively small investment. On the other hand, the chance of losing investment is high, making it very risky investment.

Figure 7-01 Gold and Platinum prices



7.2 Univariate Stationary Test Results of Platinum Price Series

To avoid spurious and unreliable results caused by using non-stationary time series, the characteristics and stationarity of each price series is necessary to be assessed. Data transformation is to ensure regression results are consistent and reliable. The robust Phillips-Perron (PP henceforth) (Phillips and Perron, 1988) nonparametric tests and the Augmented Dickey-Fuller (ADF henceforth) (Dickey and Fuller, 1979) unit root tests are utilized in this research to check the stationarity of all the index, futures and spot price series of platinum.

The null hypothesis of both ADF and PP unit root tests is all platinum price series contain a unit root, against the alternative that all these series are stationary. The null should *not* be rejected if absolute value of the test statistics is smaller than the absolute value of the corresponding critical value in certain degree significance; otherwise, reject it (Yang and Leatham, 1999, Yang et al., 2001). Both of an intercept and linear time trend were included on both of level and first differences in the tests. Bandwidth in PP tests is by Bartlett kernel, and number of optimal lag in the ADF is selected by Schwarz Information Criteria (SIC) (1978). The source of critical values for rejection of the unit root null hypothesis in both tests is provided by Davidson and Mackinnon (1993). In order to make all series stationary, first differences of the series are taken if null cannot be rejected at level.

The results of the PP and ADF unit root tests on New York Mercantile Exchange (NYMEX henceforth) platinum futures price are presented in Table 7-01 and Table 7-02 respectively, where results for $I(1)$ versus $I(0)$ (level prices) allocate in Panel a, and results for $I(2)$ versus $I(1)$ (first price differences) is in Panels b. In Panels a of Table 7-01 and Table 7-02, it can be seen that the absolute values of computed PP and ADF tests statistics for natural logarithm values of NYMEX platinum futures price are less than the absolute values of its 10% critical values, thus, the null of unit root is not rejected. It indicates that log-level NYMEX platinum futures price is non-stationary at the 10% level of significance, and then the PP and ADF tests are performed on the series' first differences.

In logarithmic first differences at Panels b of Table 7-01 and Table 7-02, the absolute values of calculated PP and ADF statistics for NYMEX platinum futures price are far greater than the absolute values of 1% critical values, and the null of unit root is rejected. The series thus is found to be stationary at 1% significant level or better and the order of integration is said to be one, $I(1)$.

Table 7-01

Phillip-Perron (PP) Unit Root Tests for Logarithmic MYMEX Platinum Futures Price

$\Delta Y_t = a_1 + \beta_1 Y_{t-1} + \varepsilon_t$

Panel a	Level (lnP)				
Variable	BW	PP Test Statistic	Prob.#	Critical Value at 10%	Stationarity
$\mathrm{FUS}^{\mathrm{MYMEX}}$	13	2.300108	1.0000	-3.127895	Non-stationary $I(1)$
Panel b	First difference (ΔlnP)				
Variable	BW	PP Test Statistic	Prob.#	Critical Value at 1%	Stationarity
FUS^{CBOT}	17	-46.79286***	0.0001	-3.433312	Stationary $I(0)$

Note:
All the price series are from March of 2000 to February of 2008
Trend and intercept are added in test at level, apart from only intercept is contained in unit root test of CMXC; and only intercept is added at difference level
BW is the bandwidth chosen by Newey-West automatic truncation lag
#MacKinnon (1996) one-sided p-values.
Asterisks denotes: *** Significant at 1% level; ** Significant at 5% level; * Significant at 10% level

Table 7-02

Augmented Dickey-Fuller (ADF) Unit Root Tests for Logarithmic MYMEX Platinum Futures Price

$$\Delta Y_t = a_0 + \beta_1 Y_{t-1} + \sum_{t=1}^{n} \beta_t \Delta Y_{t-i} + \varepsilon_t$$

Panel a	Level (lnP)				
Variable	Lag Length	ADF Test Statistic	Prob.#	Critical Value at 10%	Stationarity
$\mathrm{FUS}^{\mathrm{NYMEX}}$	0	2.740943	1.0000	-3.411980	Non-stationary $I(1)$
Panel b	First difference (ΔlnP)				
Variable	Lag Length	ADF Test Statistic	Prob.#	Critical Value at 1%	Stationarity
FUS^{CBOT}	0	-46.12329***	0.0001	-3.433312	Stationary $I(0)$

Note:
All the estimated price series are from March of 2000 to February of 2008
Trend and intercept are added in test at level; and only intercept is added at difference level
Optimal lag lengths chosen by Schwarz Info Criterion (SIC)
Asymptotic critical values are from Davidson and Mackinnon (1993)
#MacKinnon (1996) one-sided p-values.
Asterisks denotes: *** Significant at 1% level; ** Significant at 5% level; * Significant at 10% level

The results of testing non-stationarity of all the platinum price series, including indexes, futures and spot prices in logarithmic levels and first differences are presented in Tables X3-01 and Table X3-02 in Appendix III. All the platinum price series appear to be non-stationary in log-levels at 10% level of significance and stationary in log first differences 1% level of significance based on the reported p-values. It can conclude that all log-first differenced platinum price series are clearly stationary or $I(0)$, thus all log-level platinum price series are integrated of the same order $I(1)$.

Both cointegration (long-run relationship) and lead-lag (short-term causality) relationships are based on the non-stationarity of the time series. Given the results from both PP and ADF unit root tests suggest that all natural logarithm platinum price series are integrated of order 1, $I(1)$. Thus, it allows testing for the existence of cointegration between pairwise log price series as the logical next step in the empirical analysis.

7.3 Empirical Evidence of H1a: Existence of Long-run Cointegration between Prices of Pairwise Platinum Markets

Cointegration theory suggests that two non-stationary series having same stochastic trend, tend to move together over the long run (Engle and Granger, 1987). However, deviation from long run equilibrium can occur in the short run. The existence of cointegration thus, is the prerequisite of examining market efficiency and price discovery and lead-lag relationship between markets, and the precondition of conducting error correction models. Therefore, in order to understand price relationship between platinum futures / index and spot markets, it needs to identify the existence of cointegration between them.

7.3.1 Determination of the Rank of Cointegration on Platinum Price Series (*Bivariate cointegration tests*)

The lag length for Cointegration test and Error Correction Model is selected on minimum value of the Akaike's Information Criterion (AIC) and the Schwarz Criteria (SC). Two information criterions determine up to seven lags length for the regressions in the research. The appropriate lag length proceeds to test cointegration and to whiten the error term for each of the estimations in relation to platinum is presented in Tables X3-03 in Appendix III.

7.3.2 Results of Cointegration Tests on Platinum Price Series

The platinum indexes, futures and spot price have all been found to be non-stationary in levels and stationary after first order difference. These $I(1)$ variables meet a possibility for the cointegration relationship between the two markets. Pairwise Engle and Granger's (EG's henceforth) and Johansen's cointegration approachesare employed to examine long-run relationship between two price series. The null hypothesis of both estimations is cointegration relationship between two price series does not exist.

The results of unit root test for residual error from OLS regression of Tokyo Commodity Exchange (TOCOM henceforth) platinum futures price and Australia Perth Mint (Perth Mint henceforth) platinum spot price are shown in Table 7-03. Both ADF and PP test results show clearly that the null of non-stationary is rejected at 1% level of significance, which suggests the residual error is stationary, thus the price series of TOCOM futures price and Perth Mint spot price are cointegrated.

Table 7- 03

EG's Cointegration Tests on
TOCOM Platinum Futures Price and Australia Perth Mint Platinum Spot Prices

ADF test: $\Delta Y_t = a_0 + \beta_1 Y_{t-1} + \sum_{t=1}^{n} \beta_t \Delta Y_{t-i} + \varepsilon_t$ PP test: $\Delta Y_t = a_1 + \beta_1 Y_{t-1} + \varepsilon_t$

Variables	ADF Test	PP Test	H_0: $I(1)$	Conclusion
FJP and SAU	-2.740427***	-3.153528***	rejected	Cointegrated

Notes:
*** Statistically significant at 1% level; ** Statistically significant at 5% level

The EG's cointegration results of all the pairwise log platinum price series, presented in Table X3-04 to Table X3-07 in Appendix III, show residual error from every OLS regression is stationary, and thus there is the cointegration relationship between platinum futures and spot prices, and between platinum index and platinum spot price, given by EG's methods.

On the other hand, the results of Johansen's (1991, 1995) cointegration test on TOCOM platinum futures price and Perth Mint platinum spot price are shown in Table 7-04. It clearly shows that the null hypothesis of non-cointegration cannot be rejected at the 5% significant level in both of trace and max eigenvalue tests. Thus, no cointegration between TOCOM futures price and Perth Mint spot price exists.

Table 7- 54

Johansen's Cointegration Tests on
Logarithmic TOCOM Platinum Futures Price and Logarithmic Australia Perth Mint Platinum Spot Prices

$$\lambda_{trace}(r) = -T \sum_{i=r+1}^{p} \ln(1-\widetilde{\lambda_i}) \qquad \lambda_{Maximal\ Eigenvalue}(r, r+1) = -T \ln(1-\widetilde{\lambda_{r+1}})$$

Price Variables	H_0: rank=r	H_1: rank=r	λ_{trace} Statistics	Critical Values	Conclusion	H_0: rank=r	H_1: rank=r	λ_{max} Statistics	Critical Values	Conclusion
FUS^{TOCOM} and SAU	r ≤ 0	r > 0	14.96559	25.87211	Non-Cointegrated	r = 0	r = 1	10.34917	19.38704	Non-Cointegrated
	r ≤ 1	r > 1	4.616421	12.51798	Non-Cointegrated	r = 1	r = 2	4.616421	12.51798	Non-Cointegrated

Notes:
r is the number of cointegrating vectors
* denotes rejection of the hypothesis at the 0.05 level
Critical Value is at 5% significant

The results of Johansen cointegration tests on the pairwise log platinum price series, presented in Table X3-08 to Table X3-10 in Appendix III, show the null hypothesis of one cointegrating vector exists can be rejected at 5% level of significance. It implies that NYMEX platinum futures is cointegrated with (any of concerned) platinum spot prices from Perth Mint, New York City free market, London Platinum and Palladium Market and Englehard; US index (of either S&P or Merrill Lynch) is cointegrated with (any of concerned) platinum spot prices. On the other hand, the null hypothesis of one cointegrating vector exists cannot be rejected at 5% level of significance shown in Table X3-11 in Appendix III, which implies that Japan TOCOM platinum futures price and any of tested platinum spot prices are independent, given an opposite suggestion on EG's cointegration conclusions.

These conflicting results between two cointegration approaches have been found in both of gold and silver estimations. Johansen's cointegration tests suggest that TOCOM futures contracts of gold, silver and platinum do not have a close relationship with their spot price from partial overlapping or non-overlapping markets. It may imply that TOCOM precious metal futures market is not efficient, and there are fewer opportunities for international precious metal investors to gain profits at TOCOM. As a result, liquidity of TOCOM precious metal futures contracts and information embedded into its precious metal futures prices are limited. This may suggest market regulators to amend market rule to lower market entrance requirements or remove entrance bias to international traders. In this case, TOCOM can't offer international precious metal investors advanced information for their investment activities. As a result, these investors may not be interested in TOCOM.

In summary, as what has been found in gold and silver markets, the null hypothesis of non-cointegration between TOCOM platinum futures price and its international platinum spot prices has been rejected by EG's cointegration test, but not by Johansen's cointegration test. The null hypothesis between US platinum futures price / index and platinum spot prices has been rejected both EG's and Johansen's cointegration tests. Hence, the existence of cointegration relations allows examinations of unbiasedness hypothesis, price discovery and price causal relationship to be available.

7.4 Empirical Evidence of H2a: Unbiased Predictor of Platinum Future Spot Prices

Cointegrated stationary platinum price series can be used to test the unbiasedness hypothesis that the futures price and index are the unbiased predictors of future spot price by EG's and Johansen's Vector Error Correction Model (VECM henceforth). A restriction on the cointegrating parameters to be (1, -1) is imposed into VECM. The null hypothesis that financial price is an unbiased predictor of spot price is rejected if computed statistics of Chi-square is significant. Optimal lag length put into VECM is selected by both Schwarz Information Criteria (SIC) and Akaike's Information Criterion (AIC).

The empirical results show supporting evidence of cointegration among the series considered in all markets, apart from TOCOM platinum futures price, due to absence of essential condition of cointegration. The estimation results of unbiasedness of all pairwise cointegrated non-stationary platinum price series are presented in Table 7-05 below. The empirical evidence suggests that none of platinum futures / index markets is efficient and unbiased in the long-run. These results confirm that these platinum futures prices / index do not perform this fundamental economic function well.

Table 7- 05

Parameter Restriction on Platinum Markets

Platinum Markets	Chi-square (1)	Probability	Unbiased Predictor of Spot Price
NYMEX platinum futures price and Australia platinum spot price	8.412260***	0.003727	No
NYMEX platinum futures price and US platinum spot price	9.423826***	0.002142	No
NYMEX platinum futures price and US New York platinum spot price	7.791050***	0.005251	No
NYMEX platinum futures price and UK platinum spot price	7.509332***	0.006138	No
Merrill Lynch's Platinum index and Australia platinum spot price	23.02419***	0.000002	No
Merrill Lynch's Platinum index and US platinum spot price	19.42625***	0.000010	No
Merrill Lynch's Platinum index and US New York platinum spot price	19.92351***	0.000008	No
Merrill Lynch's Platinum index and UK platinum spot price	18.71615***	0.000015	No
S&P's Platinum index and Australia platinum spot price	15.70113***	0.000074	No
S&P's Platinum index and US platinum spot price	16.23828***	0.000056	No
S&P's Platinum index and US New York platinum spot price	14.55467***	0.000136	No
S&P's Platinum index and UK platinum spot price	14.43424***	0.000145	No

Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level;

Taking a look at the unbiasedness tests results on gold, silver and platinum, it is interesting to notice that gold has more unbiased predictors of the future gold spot price, silver has less and platinum has none. Among these precious metals, most of the gold is stored as bank reserves, and there is relatively small amount of gold for industrial use and private investment. The price of gold may be not only affected by supply and demand. However, gold futures prices and indexes have the largest trading volume and market liquidity than the other two precious metal futures contracts and indexes. Silver is used on both industry and investment. Silver has larger production than gold, however, its futures and index trading liquidity is smaller than gold's. Platinum has smallest production and almost of all of them is used on industrial productions. The price of platinum is heavily decided by demand and supply forces. The metals' unique characters may have impact on their market efficiency. One of the reasons may be that futures and index of the metal with greater industrial uses are less efficient to be unbiased predictor to its future spot price. Or large trading volume and market liquidity of futures and index markets would boost their unbiasedness to forecast future spot prices.

7.5 Empirical Evidence of H3a: Price Discovery Role of Platinum Futures Prices or Indexes

An error correction model exists, once a co-integration relationship between two $I(1)$ price series is discovered (Granger 1986 and Engle and Granger 1987). The cointegration regression deals with long run property of relationship, while the short term dynamics is observed explicitly by VECM. The speed adjustment parameters a in VECM are to measure the speed with which deviations from the long-run relationship are corrected by changes in the spot and futures prices. The larger absolute form of significant a represents the higher level of adjustment and greater response of the series to deviations from long-run equilibrium and the price gap between the series will be very stable. The optimal lags in VECM are selected by the minimization of the Akaike information criterion and minimization of the Schwarz Bayesian information criterion.

The results of the Johansen's VECM on NYMEX platinum futures price and Australia's platinum spot price displayed in the Table 7-06 below, where the coefficients statistics of adjustment parameters a are significant at 1% level both equations. It means both prices contribute to price discovery to attain a sustainable long-term equilibrium. However, the absolute value of a_1 from futures price equation is greater than the absolute value of a_2 from spot price equation. It suggests that NYMEX's platinum futures price adjusts significantly back to the equilibrium and makes greater contribution to price discovery.

The adequacy of the model is checked by analysing the standardized residuals. After standardising there should be no autocorrelation in the residuals and squared residuals, if the model is well specified. This diagnostic check is performed by analysing the Lagrange multiplier (LM) tests of the series. The lag lengths chosen to whiten the error term and as tests for autocorrelation LM tests for the presence of autocorrelation up to the 12th order are reported in Table 7-07, and the p-values of the LM test are shown that no problem with autocorrelated residuals occur.

Table 7- 06

Johansen's Vector Error Correction Model on
logarithmic US NYMEX platinum futures price and logarithmic Australia platinum spot price

FUS_t	Coefficient	Standard Error	t-Statistics	SAU_t	Coefficient	Standard Error	t-Statistics
β_1	1			β_2	-1.025741***	0.00833	-123.190
μ_1	0.000756**	0.00031	2.42620	μ_2	0.000425*	0.00024	1.80608
a_1	0.043375***	0.01140	3.80484	a_2	-0.061806***	0.01508	-4.09737
ρ_{111}	-0.002297	0.02649	-0.08673	ρ_{211}	0.538344***	0.02002	26.8948
ρ_{112}	0.035438	0.03122	1.13501	ρ_{212}	0.231017***	0.02360	9.79036
ρ_{113}	-0.114927***	0.05387	-2.13326	ρ_{213}	0.150544***	0.02375	6.33811
ρ_{114}	-0.022948	0.03125	-0.73440	ρ_{214}	0.083481***	0.02362	3.53507
ρ_{115}	-0.153169***	0.05170	-2.96241	ρ_{215}	0.026706	0.02207	1.21019
ρ_{121}	-0.023510	0.03327	-0.70655	ρ_{221}	-0.272162***	0.02515	-10.8229
ρ_{122}	-0.051843	0.03396	-1.52677	ρ_{222}	-0.201449***	0.02566	-7.85006
ρ_{123}	0.046676	0.03357	1.39024	ρ_{223}	-0.114059***	0.02537	-4.49522
ρ_{124}	-0.005679	0.03240	-0.17526	ρ_{224}	-0.036862	0.02449	-1.50541
ρ_{125}	-0.035659	0.02534	-1.40712	ρ_{225}	-0.014304	0.01915	-0.74685
R^2	S.D. dependent	S.E. equation	F-statistic	R^2	S.D. dependent	S.E. equation	F-statistic
0.019218	0.014123	0.014024	3.656978	0.348276	0.013094	0.010599	99.73716

Notes

In the estimated ECM results, β_1 and β_2 cointegration parameters, μ_1 and μ_2 are intercepts, a_1 and a_2 are coefficients for the Error correction term, ρ_{11i} is the coefficient for ΔFUS_t at lag i in the ΔFUS_t equation, ρ_{12i} is the coefficient for ΔSAU_t at lag i in the ΔFUS_t equation, ρ_{21i} is the coefficient for ΔFUS_t at lag i in the ΔSAU_t equation, ρ_{22i} is the coefficient for ΔSAU_t at lag i in the ΔSAU_t equation

Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level; * Statistically significant at 10% level

Table 7- 07

VEC Residual Serial Correlation LM Tests
Null Hypothesis: no serial correlation at lag order h
Sample: 3/24/2000 2/29/2008
Included observations: 2065

Lags	LM-Stat	Prob	Lags	LM-Stat	Prob
1	10.83409	0.0285	7	8.288281	0.0816
2	12.26578	0.0155	8	10.65901	0.0307
3	87.19446	0.0000	9	11.58071	0.0208
4	34.83269	0.0000	10	5.679943	0.2244
5	4.335474	0.3625	11	14.81534	0.0051
6	1.086971	0.8963	12	2.044276	0.7276

Probs from chi-square with 4 df.

In EG's bivariate VECM, the residuals from price series have been embed in a VECM in order to gauge short- and long-run Granger causality which allows formal classification of lead/lag behaviour. The lag length of the EG's VECM is chosen on basis of the Akaike information criterion and Schwarz Bayesian information criterion. The EG's VECM estimation results on NYMEX platinum futures price and Perth Mint platinum spot price shown in Table 7-08 where the statistical significance and absolute values of adjustment parameters a_1 and a_2 in futures and spot prices equations respectively indicate NYMEX platinum futures price makes greater contribution on re-establishing equilibrium price than Perth Mint platinum spot price does. The p-values of the LM test in Table 7-09 show a presence of weak serial correlation in residuals, which indicates the residuals appear reasonable well behaved.

Table 7- 08

EG's Vector Error Correction Model on
logarithmic US platinum futures price and logarithmic Australia platinum spot price

FUS_t	Coefficient	Standard Error	t-Statistics	SAU_t	Coefficient	Standard Error	t-Statistics
β_1	1			β_2	-1.019335***	1.8E-07	-5574726
μ_1	0.000550***	0.00022	2.49174	μ_2	0.000513**	0.00022	2.37066
a_1	0.308241***	0.01717	17.9482	a_2	-0.685794***	0.01751	-39.1745
ρ_{111}	0.382055***	0.02063	18.5188	ρ_{211}	0.374811***	0.02024	18.5191
ρ_{112}	0.174544***	0.02234	7.81304	ρ_{212}	0.171236***	0.02192	7.81323
ρ_{113}	0.093229***	0.02247	4.14819	ρ_{213}	0.091458***	0.02205	4.14810
ρ_{114}	0.052090**	0.02220	2.34693	ρ_{214}	0.051106***	0.02177	2.34711
ρ_{115}	0.031500	0.02068	1.52321	ρ_{215}	0.030905	0.02029	1.52337
ρ_{121}	-0.200266***	0.02387	-8.38914	ρ_{221}	-0.196467***	0.02342	-8.38920
ρ_{122}	-0.158531***	0.02414	-6.56629	ρ_{222}	-0.155520***	0.02369	-6.56617
ρ_{123}	-0.066760***	0.02389	-2.79439	ρ_{223}	-0.065490***	0.02344	-2.79427
ρ_{124}	-0.027631	0.02293	-1.20489	ρ_{224}	-0.027102	0.02250	-1.20467
ρ_{125}	-0.020811	0.01793	-1.16045	ρ_{225}	-0.020422	0.01759	-1.16076
R^2	S.D. dependent	S.E. equation	F-statistic	R^2	S.D. dependent	S.E. equation	F-statistic
0.449835	0.013094	0.009740	139.8158	0.508640	0.014123	0.009929	177.0137

Notes
In the estimated ECM results, β_1 and β_2 cointegration parameters, μ_1 and μ_2 are intercepts, a_1 and a_2 are coefficients for the Error correction term, ρ_{11i} is the coefficient for ΔFUS_t at lag i in the ΔFUS_t equation, ρ_{12i} is the coefficient for ΔSAU_t at lag i in the ΔFUS_t equation, ρ_{21i} is the coefficient for ΔFUS_t at lag i in the ΔSAU_t equation, ρ_{22i} is the coefficient for ΔSAU_t at lag i in the ΔSAU_t equation
Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level; * Statistically significant at 10% level

Table 7- 09

VEC Residual Serial Correlation LM Tests
Null Hypothesis: no serial correlation at lag order h
Sample: 3/24/2000 2/29/2008
Included observations: 2065

Lags	LM-Stat	Prob	Lags	LM-Stat	Prob
1	5.932790	0.2042	7	1.323440	0.8574
2	6.327431	0.1760	8	3.137845	0.5350
3	2.730155	0.6039	9	9.295489	0.0541
4	3.556954	0.4693	10	8.574587	0.0727
5	7.283866	0.1216	11	7.157578	0.1278
6	9.217351	0.0559	12	0.760322	0.9437

Probs from chi-square with 4 df.

According to the EG's and Johansen's VECM estimations in relation to platinum price series in Table X3-12 to Table X3-18 in Appendix III, both types of VEC estimations support that New York Mercantile Exchange platinum futures price is the main contributor to price discovery rather than any of tested platinum spot price from Perth Mint, New York City free market, London Platinum and Palladium Market and Englehard; platinum indexes of Merrill Lynch and Standard & Poor are the main contributors to price discovery respectively rather than platinum spot prices of Perth Mint, and Johansen's estimations suggest Merrill Lynch index is the solo contributor to future spot prices of New York free market, London Platinum and Palladium Market and Englehard.

As Johansen's VECM on TOCOM platinum futures price cannot be carried out due to absence of cointegration in previous step, EG's VEC estimations suggest that platinum futures price of TOCOM is the main contributor to price discovery rather than spot prices of New York free market, London Platinum and Palladium Market and Englehard, but it makes less contribution to Perth Mint platinum spot price.

Coinciding with findings in gold and silver markets, platinum futures prices and indexes have a greater speed of adjustment in discovery of the next moment price in most of cases. Hence, the hypothesis that futures prices and indexes are the primary informational sources of spot prices during 2000 to 2008 fails to be rejected in majority of cases platinum market. It implies platinum futures and index markets are more efficient to available coming information and discover new price than platinum cash markets.

7.6 Empirical Evidence of H4a: Short-term Causality of Platinum Price Series

Although a long-run equilibrium has been found, short-term deviations may exist and need to be corrected in next period to maintain the equilibrium. As US platinum futures and index markets have been found to be cointegrated with its worldwide platinum cash markets, the lead-lag relationship between these platinum futures / index and spot price can be explored. The short-term price dynamics can be identified by vector error correction mechanism. This temporal causality can be assessed by examining the statistical significance of parameter ρ in the VECM model, relative magnitudes of error correction coefficients and coefficients on the lagged variables.

As result of Johansen's VECM estimation on NYMEX platinum futures price and Perth Mint platinum spot price shown in the Table 7-06, with the lag length decided by Akaike information criterion and Schwarz Bayesian information criterion. The statistically significant coefficients of lags ρ_{11i} and ρ_{12i} in first differences NYMEX platinum futures price equation show the past move of Perth Mint platinum spot price and NYMEX platinum futures price has impact on current move of NYMEX platinum futures price respectively. The coefficients ρ_{21i} and ρ_{22i} in first differences for the Perth Mint platinum spot price equation are statistically significant, indicating that the past movements of NYMEX platinum futures price and Perth Mint platinum spot price have an impact on the current movement of Perth Mint platinum spot price. These results for lags ρ indicate that NYMEX platinum futures price unidirectionally leads Perth Mint platinum spot price.

As EG's VECM estimation on NYMEX platinum futures price and Australia Perth Mint platinum spot price shown in the Table 7-08, with the lag length decided by Akaike information criterion and Schwarz Bayesian information criterion. The statistically significant coefficients of lags ρ in both equations show past move of Perth Mint platinum spot price has impact on current move of itself and NYMEX platinum futures price; and the past move of NYMEX platinum futures price has impact on current move of itself and Australia's platinum spot price. These figures of lags ρ indicate NYMEX platinum futures price has greater causality power over Australia Perth Mint platinum spot price based on their bidirectional causality relationship. Thus, the finding of NYMEX platinum futures price leads Perth Mint platinum spot price has been verified by Johansen's and EG's VECMs.

The results of all the Johansen's and EG's VECM applied on cointegrated platinum price series are displayed in Table X3-12 to Table X3-18 in Appendix III. Based on either unidirectional or bidirectional causality relationship, the hypothesis that platinum futures and index markets lead platinum cash market cannot be rejected in most of cases, confirmed by both VECM approaches:

NYMEX platinum futures price leads New York City free market platinum spot price, but not vice versa. Based on a bidirectional causality relationship, NYMEX platinum futures price and Englehard platinum spot price have similar impact over each other; NYMEX platinum futures price and Perth Mint platinum spot price cause each other with similar power as well; New York Mercantile Exchange platinum futures price is caused by London Platinum and Palladium Market platinum spot price.

According to Johansen's VECM results, NYMEX platinum futures price dominates the short-term price discovery to all tested platinum spot prices. Merrill Lynch platinum index has stronger impact on platinum spot prices of Perth Mint and Englehard respectively, but not vice versa. Meanwhile, Merrill Lynch platinum index leads platinum spot prices from New York City free market and London Platinum and Palladium Market respectively. S&P platinum index has stronger lead than each of platinum spot prices has, based on a bidirectional causality relationship.

Moreover, EG's VECM results suggest platinum spot price has equally or almost equally causality power as platinum futures or index has in all cases, including TOCOM platinum futures price. As absence of long-run equilibrium relationship between TOCOM platinum futures market and each of platinum cash markets, Granger causality test is employed to testify direction of casualty between two price series.

Both Johansen's and EG's VECM results suggest platinum futures and index lead platinum spot prices; meanwhile, platinum spot prices also make correction to move forwards to equilibrium price. Thus, many cases show a bi-directional relationship between two markets, which means platinum futures / index and spot prices have predictive power over future spot price change.

7.6.1 Direction of Causality between Non-Cointegrated Platinum Price Series

Granger causality test is used to identify the long-run causal relationship between non cointegrated platinum prices series. Thus, the previous value of one price can predict current price of the other price, even they are not cointegrated. The hypothesis of Granger causality tests that prices do not Granger cause each other can be rejected, if F statistic is significant.

As the result of Granger causality test shows in Table 7-10, it indicates that the hypothesis of London Platinum and Palladium Market platinum spot price does not Granger cause TOCOM platinum futures price, and the hypothesis of TOCOM platinum futures price does not Granger cause London Platinum and Palladium Market platinum spot price are rejected, because of the significant F statistics. Therefore, it reveals that the past value of London Platinum and Palladium Market platinum spot price can be used to predict current value of TOCOM platinum futures price, and the past value of TOCOM platinum futures price can be used to predict current value of London Platinum and Palladium Market platinum spot price.

Table 7- 10

Pairwise Granger Causality Tests of Japan TOCOM Gold Futures Price and Australia Platinum Spot Price
Sample: 3/24/2000 2/29/2008
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
SAU does not Granger Cause FJP^{TOCOM}	2069	29.3592***	3.E-13
FJP^{TOCOM} does not Granger Cause SAU		37.6738***	9.E-17

Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level

The rest results of Granger causality tests are displayed in Table X3-19 at Appendix III. It indicates that platinum spot prices from Perth Mint and Englehard Granger and New York City free market cause TOCOM platinum futures price respectively, but not vice versa. According to the finding, TOCOM platinum futures price is not a good predictor to platinum spot prices in the long run.

7.7 Summary of Analysis on Platinum Price Series

The relationship between platinum financial and spot prices is investigated using the most complete data set available. Results are consistent with the findings in gold markets, in that cointegration tests reveal long-run equilibrium relationship between US platinum futures / index and spot price. Although US platinum futures and index markets may play a bigger role long-run price discovery, spot prices also plays a role in this respect.

Futures contracts are traded for the delivery of the underlying asset at various points in the future, and they reflect the current expectations of the market about the course of cash prices at those points in the future (Kavussanos & Nomikos 1999). Futures markets are thus, expected to provide a platform for management of price variability and risk associated with production and trading of commodities. If the market is efficient, then the futures prices are the unbiased predictor of subsequent spot price. None of platinum futures and index markets is found to be unbiased in this study; therefore, it implies weak- or semi-strong form market efficiency, and current platinum futures and index are unlikely to predict accurately future spot price.

Johansen's VECM results state that unidirectional causality runs from New York Mercantile Exchange's platinum futures price to platinum spot price of Perth Mint, Englehard, London Platinum and Palladium Market and New York City free market has been verified by Johansen's VECM. Meanwhile, Merrill Lynch platinum index has stronger impact on Perth Mint and London Platinum and Palladium Market platinum spot prices respectively on a bidirectional causality relationship, and it also leads platinum spot prices from Englehard and New York City free market respectively, but not vice versa. Based on a bidirectional causality relationship, S&P platinum index has stronger impact on platinum spot prices from Perth Mint and London Platinum and Palladium Market respectively. S&P platinum index leads platinum spot prices from New York City free market and Englehard respectively, but not vice versa.

As we can see, platinum futures prices and indexes show dramatic impact on all platinum spot prices in either unidirectional or bidirectional causal relationship reflected in Johansen's VECM results; on the other hand, bidirectional causal relation has been found existing in all estimations of EG's VECM and almost equally causal power from both sides is suggested. Investigating price relationship finds that platinum futures prices and indexes remain the key source of price discovery in both long-run and short-term, and provides important information to the traders regarding the prospective direction of price movement in the spot market. However, platinum futures prices and indexes are not unbiased predictors, which implies platinum futures prices and indexes cannot provide market participants accurate forecasting for future spot price. The findings of bi-directional lead-lag relationship and futures / index prices lead spot price in platinum are very similar to gold market's results. But gold futures and indexes conduct a more dominantly strong leading role than platinum's. It may be because platinum can be treated as a store of value in jewellery form by private owners, as large portion of its production are used on making jewellery, and its volatile price and scarcity make it interested to investors, hence, platinum possess similar characters of gold.

7.7.1 Economic Interpretation of Results

As technology and the economy develop the result may be a dramatic increase in the demand for platinum, which may trigger its spot price increase and price volatility as well. More investors step into futures market to protect them from fluctuation on price. The discovery of cointegration existence between US platinum futures / index and platinum spot price by both ECM estimations suggests that there is useful information for investors. As further investigation found that platinum futures / index prices are the main price discovery contributors in the long run, thus investors can use this information with futures / index prediction. Because, US platinum futures / index lead platinum spot price in the long run, hedgers can be motivated and informed by government to use US platinum futures / index markets as the optimal choice on eliminating and protecting from risk in the future.

One of the interesting findings in platinum market is that none of the US platinum futures and index is an unbiased predictor of future platinum spot price and thus, none of these US platinum futures and index markets is efficient. This finding has an important implication for market participants in platinum, As Fama (1970) states no profitable opportunities are left unexploited in an efficient financial market, the arbitrage definition of non-efficiency presumes that all profitable arbitrage opportunities come to be exploited and reflected in these platinum futures, index and spot prices. Arbitrage shifts mispricing caused by any deviation of the expected returns consistent with supernormal profits. Traders can speculated in the futures / index market on the future level of the spot price exploiting profit consistently. However, market regulators need to take more actions in order to contribute to market efficiency and avoid over-arbitrage. These actions concern the price transparency, the further decrease in margins and trading costs, the development of more effective trading systems and market monitoring and the market liquidity by increasing the participation from local and foreign institutional investors (Kenourgios 2005).

With the further findings of US platinum futures and index lead platinum spot price in the short-term, the empirical results in platinum markets suggest that US platinum futures / index provide economic benefits, such as information dissemination, price discovery and efficient allocation of resources between spot and futures / index markets. Besides, it may encourage speculators increase investment in platinum markets driven by expectation of more returns.

Chapter 8

Summary and Conclusions

Since the introduction of futures markets, the impact of futures price on future spot price and the relationship between them have been a long term debate. The investigation of these issues in precious metals market is attractive due to the unique characteristics of individual precious metals in both financial and industrial markets. Gold and silver have been attracted people's interest for thousands of years and valued as a global currency, a commodity, an investment and jewellery. Gold is considered as a potential hedging means and as a safe haven, hence, gold demand is not driven by industrial uses (Davidson et.al 2003, Baur and Lucey 2007). Silver is used as hedge against economic uncertainty and as reserve assets held by central banks. Also, silver is a vital industrial commodity and critically important in electronics and other high-tech applications. Platinum is among the world's scarcest metals. Despite only limited availability of it, it has given the great contributions to modern scientific progresses. Industrial use occupies approximately two thirds of the total demand for platinum (O'Connell, 2005).

This study attempts to empirically improve understanding of the nature of the price discovery mechanism, market efficiency, and the long run and in particular, the short-run temporal dynamic relationships between worldwide financial and spot markets of precious. Drawing on econometric analysis, the role of financial markets in providing price information and the temporal causal framework to spot markets have interesting implications to gain insight on the directionality of information generation and assimilation in the commodities markets.

The findings provide some quantitative empirical insights into these concerned issues on precious metals across spatial market, which extends the current literature and can serve as a starting point for further research in that area as well. Despite precious metals being important commodities for the world economy, little attention has been put on the price dynamics and the pricing behaviour of precious metals. Besides, there is little investigation has been taken on the short-term mutual-affected relationship and predicting power between international mature precious metals markets. As markets across the world are tied with all kind of connections and global prices of precious metals are volatile when the economy is facing uncertainty. In this circumstance, policy makers, regulators and market participants are required a better understanding on how the markets prices move and how the prices in worldwide markets are interrelated.

The investigation was carried out by examining a series of hypotheses addressed on the existence of comovements between financial and spot prices for each precious metal; the financial market serves the price discovery function effectively; that of unbiased predictor of the corresponding future spot price and market efficiency of financial price can be tested through formal econometric analysis; that financial price always leads spot price; that change in current spot price is influenced by change in past financial price in the short-term. Daily data of gold, silver, and platinum over the period of March 2000 to February 2008 is obtained for this study, sample futures markets are daily closing price from well developed futures exchanges in US and Japan; sample indexes are from US main stock Merrill Lynch and S&P; and daily fixing price overseas spot markets places in Australia, Mexico, UK, and US.

Results from two different unit root tests indicate all the price series are I(1). To account for the non-stationarity in the data, two cointegration approaches of Engle-Granger's (EG's henceforth) residual approach and the Johansen procedure, allow examining the existence of a long-run relationship between both markets is demonstrated. In the absence of cointegration, test for causality in the traditional framework with the error correction term omitted is preceded. Two versions of bivariate Vector Error Correction Model (VECM henceforth) that has been suggested to have a much higher predictive ability than any of the traditional models by Nwachukwu and Egwaikhide (2007), are employed to test the Efficient Market Hypothesis (EMH), price discovery efficiency, and short-run causal dynamic linkages between two precious metal markets.

8.1 Long-run Relationship

Although these precious metals have their unique properties and their prices are driven by different incentives—either by investment section or industry section or both, their findings on long-run relationship are consistent. The results confirm allegations that the Tokyo Commodity Exchange (TOCOM henceforth) futures price provides informed prices that cannot be embodied in these spot markets. And thus, the TOCOM futures prices of precious metals are not functioning properly to spatial precious metals spot markets. It results to the presence of factors determined the future spot prices of overseas miners, refiners, producers and traders in this study that are not reflected in the futures prices of contracts with extensive expiration date.

On the other hand, US precious metal futures and index markets have been found integrated with the world spot markets. News from these precious metal financial and index markets can have big impact on those spot precious metal prices. It may due to the fact future commodity markets are more innovative that enables them to expose the all available information with respect to the price of the commodities and investors' behaviour in the market (Mahalik et al., 2009). This finding of cointegration between futures/index and spot price suggests that these precious metals futures contracts and indexes are a useful vehicle for reducing overall market price risk faced by spot market participants (Mahalik et al., 2009).

These results on market integration and comovement in precious metals prices are important for the usefulness of futures and index markets to hedgers. Holthausen (1979) shows that the relationship the futures price and the expected price may affect the firm's optimal between hedging decision. Yang et al. (2001) suggest that on commodity markets, the existence of cointegration between spot and futures prices implies that cointegration has incorporated into commodity hedging decisions. Yang et al. (2001) also suggest that the existence of cointegration on commodity markets gives opportunities to improve the commodity price forecasts, particularly long-run forecasts. They recommend adding the error correction term should improve forecasts of the future spot commodity prices conditional on the current futures prices, due to the error correction term has been found to be statistically significant in explaining the spot prices for a majority of the commodities under study.

8.2 Price Discovery

The empirical findings show that futures prices and indexes for three different precious metals appear to dominate and serve effective price discovery in the long run; meanwhile, spot prices also play an important role in this respect. The different properties and uses of these precious metals do not affect this result. The long-run influence of the futures and index is greater than that of spot price, thus, achieving good price discovery efficiency in futures and index markets for all three precious metals. Moreover, the institution of manager (or investor) should understand the futures markets clearly and supervise (or invest) properly to ensure the efficiency of futures and index markets (Liu and Zhang, 2007).

US precious metal futures prices and indexes provide price discovery to spot prices. It indicates that information gets reflected first in the financial markets. Thus, US precious metal futures prices and indexes are informatively efficient and dominate the capture of new pieces of information. These findings coincide in the case of other commodity and financial futures markets. These prices thus can be called the trading ‘habitat’ of informed traders, and market agents can use them to generate more accurate forecasts of the spot price (Kavussanos and Nomikos, 2003). Informed traders can design more efficient investment and speculative trading strategies, and market with these traders is expected to see price discovery. Therefore, informed trading and market liquidity tend to reinforce each other. Microstructure theory suggests that a trading venue with high liquidity attracts informed trading and has more price discovery (Man et al., 2012).

Daily close values adopted in this study may not get transmitted as fast as information does factually. Results of this study are very difficult to say how much time it takes to go to spot market. To measure the contributions of the index and futures markets to price discovery can be stated more authoritatively only if high frequency data is used for this purpose (Raju and Karande, 2003). High frequency data is currently not available for many spot markets; therefore, they could not be employed in the equation.

However, Garbade and Silber (1983) argue that if a futures price is collected later in the day than a spot price, the futures market will appear more important for price discovery than is really the case. Partial data in this study are non-overlapped, where spot prices are collected later than futures and index. Thus, the effect of the timing of price observations may affect on regression in this study. To cope this shortcoming of data, one considered solution suggested by Garbade and Silber (1983) is to use opening price of futures in US that the afternoon London fixing price is determined slightly after 10 AM New York time.

8.3 Unbiasedness of Futures Prices and Indexes

That the financial price is an unbiased predictor of the future spot price implies there is long-run market efficiency. However, the results show neither platinum futures price nor index provides unbiased estimates to future platinum spot price. Spot price of platinum reflects its supply and demand; whilst, spot price of silver is driven by investment and industrial requirements. Few silver futures and index are efficient comparing with gold. Gold is mainly used for investment and reserve, and its financial prices have been found to be the accurate predictor for its future spot price than silver's and platinum's financial prices. It might suggest that financial price of precious metal with strong investment property offers better forecasts for their future spot price.

Success of observing unbiasedness implies given current price, no additional information, will improve the forecast of next period's price (Ghosh, 1993). Consequently, it satisfies the no-arbitrage condition of these futures and index markets, which are no private benefits to any futures (index) trading mechanism attempting to forecast prices. For instance, speculators or arbitrager's profits as well as exchange revenues from contract fees—then society will not receive the public benefits of futures trading such as price discovery (Kenourgios and Samitas, 2004). Thus, the investors are able to realize their expected future spot price of the precious metals due to the efficiency of the futures market between above markets.

Empirically, the behaviour of above spot markets may indeed be predicted. On the contrary, strong evidence of the rest of markets appears inefficient and fails to test unbiasedness. Among these inefficient markets, indices take a great proportion than futures prices. I may imply that precious metal index markets are less efficient than futures prices. One of the reasons may cause this result is that the market size and trading volume of precious metal futures markets is larger than precious metal index markets. The other possible reason is these precious metals indices do not have a high precious metal exposure. These may cause inefficient index markets, and thus, arbitrage opportunities may exist from time to time in these markets. The information incorporated in futures/index price is not considered as important to forecast future spot prices, if the market does not fulfil unbiasedness (Kenourgios and Samitas, 2004). Market participants, thus, may be misled into a costly decision if they make production decisions only on the basis of futures prices without any adjustment (Yang et al., 2001). Policy-makers then may need to re-evaluate their economic policy if affecting the commodity market is not something they desire.

However, the existence of active liquid financial markets suggests an efficient market, where no opportunities for consistent speculative profit present. As Grossman and Stiglitz (1980) discover, without such opportunities, no incentive to gather information exists, in a result, the price-discovery aspect of financial markets will collapse.

8.4 Lead–Lag Relationship

The direction of causality would be strongly from one market to the other, as informed traders in one market would commence trading and drive the reaction in the other market. The results indicate the lead–lag relationships between two markets are unidirectional causality runs from futures or index markets to spot markets in some cases. This evidence of empirical findings suggests financial price leads spot price from global precious metals markets with and without overlapping trading time. This causality relationship coincides with findings of other research on different commodities markets, such as Indian gold markets (Praveen and Sudhakara, 2006), aluminium markets and cheddar cheese markets (Figuerola-Ferretti and Gilbert, 2005b, Fortenbery and Zapata, 1997), crude oil and castor seed (Silvapulle and Moosa, 1999, Karande, 2006, Asche and Guttormsen, 2002). Besides, this evidence gives rise to help the improvement in predictions of future spot price changes based on the past information on the move of futures price or index. However, results appear that precious metals futures prices and indexes solely lead spot prices is commonly happened in examined monetary precious metals rather than industrials. Thus, market practitioners in gold, silver and platinum markets may benefit from futures and index markets clearly lead the spot market during pre-financial crisis period in 2000s.

Moreover, there is some strong evidence of futures or index leading in a bi-directional causality (feedback) between the two markets. These findings suggest that spatial precious metals spot markets do cause US financial markets, but their financial markets tend to discover new information more rapidly than spot markets do. Silvapulle and Moosa (1999) and Hua (2005) found similar causal relationship on copper, aluminium, rubber and crude oil market with overlapping trading hours. And these findings are consistent with the theory that one market reacts faster to information due to transactions costs, greater liquidity and fewer restrictions or other capital market effects that the reason of a lead-lag relation exists.

These results of causality demonstrate fluctuations in futures price or in index explain the behaviour of spot price of all monetary and industrial precious metals in most of cases. The causation patterns are in accordance with the price discovery function of a futures (index) market in that the precious metal futures prices and indexes provide some incremental explanatory power for future spot price movements of precious metals (Chen et al., 2009). Thus, futures prices and indexes from US are considerably useful for market participants such as miners, refiners, producers, buyers and investors of these precious metals to predict future spot price movements and reduce adverse price risk; besides, it also enhances the liquidity, marketability, operation efficiency, the price discovery function, and the risk-transfer function of US main futures and index markets, and to perfect futures and index market's operation mechanism. On the other hand, causality moving from spot prices towards futures or index in a bidirectional causality relationship has also been discovered. The other significance of feedback appears to be equalized, implying that the pricing of silver is more evenly divided between two markets.

Although there is bi-directional causality between these markets, most of these precious metals futures and index markets process information relatively faster than the spot market but not necessarily more accurately. Thus, the results are consistent with the view that traders in the spot market need to worry about the price movements in the spot and futures markets whereas a trader in the futures market needs to worry about the price movements in the spot and futures markets as well (Soydemir and Petrie, 2003). Thus, traders may rely more on the market with grater explanatory power. However, Turkington and Walsh (1999) argue if informed traders do indeed choose a 'habitat' it is not along the simple division of the type of instrument they choose, they may acknowledge that one market is faster at incorporating information than another, and choose the slower market. And these probably help to explain why we can only capture that a lead-lag structure exists, and not which market is more likely to be informed (Turkington and Walsh, 1999).

The existence of short-term Granger causality has been observed in this study. It implies market inefficiencies and short-term arbitrage opportunities for investors focused on sustainable investing (Olienyk et al., 1999). The causality results in this study represent investment opportunities based largely on exploiting short-term market inefficiencies, or arbitrage. Investors focused on sustainable investing shall be attracted by temporary inefficiencies of the market to make short-term arbitrage profit. Short-term arbitrage opportunities encourage traders to exploit them and hence will be quickly eliminated.

8.5Markets Liquidity and Market Efficiency

Gold has some industrial demand due to its use in manufacture, but it is primarily hold as a store of value by governments and bank; however, gold demand is increased for investment purpose or as a store of value especially under a period of economic uncertainty. As we know from Chapter 2, gold futures are heavily traded on both US and Japan exchanges, and its trading volume and trading value are greater than any of other precious metals. It suggests that gold futures markets are liquid than other precious metals. Meanwhile, it also shows in Chapter 2 that contract size and trading volume of precious metals on TOCOM is smaller than that of the New York Mercantile Exchange (NYMEX henceforth) and The Chicago Board of Trade (CBOT henceforth). It suggests that NYMEX and CBOT are larger futures markets where trading happens a great deal, and that leads NYMEX and CBOT to be more liquid than TOCOM. According to the findings, largely US futures exchange for gold is efficient. Hence, we would realize that futures market with the great liquidity and large size is more informative and efficient.

Silver has larger production and inventory than gold. Silver production is concentrate on Australia and Latin America; by contrast, gold production is widely distributed. Silver demand is mainly for manufacture use and some for investment purpose as well. When economy slows down, part of silver demand may shift from industry to investment. As shown in Chapter 2, silver futures trading volume is far less than gold. Suggested by the findings, less evidence of efficiency exists in less liquid silver markets.

After a large proportion of the few platinum production uses on manufacture and jewellery, one of the applications from remaining platinum is investment. Platinum futures trading only takes a relatively tiny part in precious metal trading volume in futures exchanges, which is far smaller than gold or silver’s trading volume. Because of platinum’s rarity, high-priced and essential use in manufacture, price of platinum is highly related to demand in manufacture and more volatile than gold. As in a strong growth economy, gold price can be stable but platinum price soar by manufacture boost. By contrast, an economy downturn may stimulate demand in gold but slow down manufacture. As a result, gold price goes up and platinum price drops. Besides, mostly platinum production is in South Africa. Any reason that South Africa reduces platinum supply may cause volatile price in world platinum markets. However, the evidence suggests that platinum futures market is not efficient.

The evidence suggests the futures prices and indexes in US play a major role in price discovery in the world precious metals markets. It means that these US futures and index markets are liquid and have sufficient information to global precious metal spot markets. Even US futures and index are with partial overlapping trading hours, they are more efficient than TOCOM that with relatively more overlapping trading hours to its spot markets. It may take account of the US futures market has a long trading history, well developed and organized system, previous merger and acquisition to form a large market. On the other hand, if a futures market is not as efficient as these US futures markets, it does not mean that this futures market is inefficient. This futures market is not informative to global spot markets, but it may be efficient to local or domestic spot markets. As we learnt from this study, market liquid is important to market efficient. If the futures market is liquid, it can be efficient and performs its price discovery function to its spot market.

The geographic separation of spot and futures / index markets may affect their efficiency. Among the markets with partial or non overlapping trading hours, the market opens early contains more information than the late opens. In this research, Australia's spot markets may take advantage to lead US futures price. The evidence shows that US futures prices still show well performing price discovery function. But the price discovery power identified on spot prices in some cases may result from its geographic advantage.

The evidence shows that US futures and index markets have varying impacts and significance on global precious metal spot markets. Investors in these markets can look beyond the domestic economic environment to determine their full risk exposures (Soydemir and Petrie, 2003, Acikalin et al., 2008).The findings suggest futures and index markets are useful for portfolio diversification strategies. And that would help commercial users and investors of precious metals to formulate their global risk management strategies and enhance the long-term profitability of trading in futures metals. The findings have practical implications for investors who expect to improve their portfolio performance in individual markets by focusing on the varying significance of the economic risk factors(Soydemir and Petrie, 2003). And arbitrageurs and speculators pay close attention to the pricing relationship of international precious metal markets, as market inefficient and arbitrage opportunities are observed.

8.6 Suggestions on Further Research

Precious metals are closely related and important to the economy. The volatile price of precious metals is reflecting the global nature of the changing markets. Stabilizing precious metals markets would be beneficial to stabilize economy. As the economy is changing and that leads change in precious metal, the price relationship between markets and how these prices react would not be the same. The futures market performance on price discovery and predicting would be necessary to reassess.

Some precious metals, such as, silver, have an increase mining production in recent years, but its inventory remains low because of its significant demand. Its demand can be driven by both manufacture and investment. As we learnt that an increase in trading volume of future contracts may improve futures market efficiency, the further investigation will offer additional means by if rising production would lead to an increase in liquidity of futures market. If large trading volume and large size of futures contract imply an efficient futures market, would markets be concentrated by less futures exchanges? In that case, the less futures exchange, the more efficiency in futures market?

Furthermore, traders may need to decide which market they should take their business. If the market size matters, would hedgers choose an efficient market, and would arbitrageurs and speculators prefer a less efficient market with more profitable opportunities to be their choice? If the location maters, would manufacturers choose a market close to the production source, and would investors pick a market proximity to the large financial centres in the world?

Moreover, the economic significance of predictability should be examined for conclusions on market efficiency of precious metals futures markets. Would geographic separation of markets may affect markets efficiency, and in what extent that can affect? Would a market close to production or a market with the most financial information may more efficient? If intraday data is available, the problem of early or late to embed market information would be solved, and test whether any predictable patterns can be detected within the data. This will be particularly useful for day-traders.

In fact, the findings by this research might be supplemented by analysis of longer term market behaviours if and when sufficient data is available. One major limitation of this framework is represented by the requirement of a large data set and also with high frequency. The identification of these limitations will also provide direction for future research.

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Appendix I

Unit Root Tests Results for Price Series of Gold

Table X1-01

Augmented Dickey-Fuller (ADF) Unit Root Tests for Various logarithmic Prices of Gold

Panel a	Level (lnP)			
Variable	Lag Length	ADF Test Statistic	Prob.#	Critical Value at 10%
FUS^{CBOT}	0	-1.997912	0.6012	-3.129619
FUS^{COMEX}	0	-2.345426	0.4085	-3.127895
FJP	0	-2.200781	0.4883	-3.127895
IML	0	-2.273338	0.4479	-3.127895
ISP	0	-2.345619	0.4084	-3.127895
SAU	1	-2.216739	0.4794	-3.127895
SMX	4	-2.709333	0.2328	-3.127897
SUK	0	-2.169555	0.5059	-3.127895
SUS	0	-2.190815	0.4939	-3.127895
Panel b	First difference (ΔlnP)			
Variable	Lag Length	ADF Test Statistic	Prob.#	Critical Value at 1%
FUS^{CBOT}	0	-30.00076***	0.0000	-3.437508
FUS^{COMEX}	0	-47.38118***	0.0001	-3.433312
FJP	0	-48.24171***	0.0001	-3.433312
IML	0	-47.42602***	0.0001	-3.433312
ISP	0	-47.23883***	0.0001	-3.433312
SAU	0	-48.74022***	0.0001	-3.433312
SMX	3	-32.78424***	0.0000	-3.433317
SUK	0	-45.80762***	0.0001	-3.433312
SUS	0	-45.48171***	0.0001	-3.433312

Note:
All the estimated price series are from March of 2000 to February of 2008
Trend and intercept are added in test at level; and only intercept is added at difference level
Optimal lag lengths chosen by Schwarz Info Criterion (SIC)
Asymptotic critical values are from Davidson and Mackinnon (1993)
#MacKinnon (1996) one-sided p-values.
Asterisks denotes: *** Significant at 1% level; ** Significant at 5% level; * Significant at 10% level

Table X1-02

Phillip-Perron (PP) Unit Root Tests for Various logarithmic Prices of Gold

Panel a		Level (lnP)		
Variable	BW	PP Test Statistic	Prob.#	Critical Value at 10%
FUS^{CBOT}	5	-2.095479	0.5471	3.129619
FUS^{COMEX}	11	-2.245488	0.4633	-3.127895
FJP	17	-1.989768	0.6060	-3.127895
IML	10	-2.207431	0.4846	-3.127895
ISP	11	-2.280153	0.4441	-3.127895
SAU	7	-2.324732	0.4197	-3.127895
SMX	67	1.298003	0.9987	-2.567452
SUK	7	-2.212407	0.4818	-3.127895
SUS	12	-2.200857	0.4883	-3.127895
Panel b		First difference (ΔlnP)		
Variable	BW	PP Test Statistic	Prob.#	Critical Value at 1%
FUS^{CBOT}	7	-30.00091***	0.0000	-3.437508
FUS^{COMEX}	11	-47.39442***	0.0001	-3.433312
FJP	18	-48.44133***	0.0001	-3.433312
IML	10	-47.41336***	0.0001	-3.433312
ISP	11	-47.23493***	0.0001	-3.433312
SAU	8	-48.69210***	0.0001	-3.433312
SMX	66	-72.55848***	0.0001	-3.433312
SUK	8	-45.80754***	0.0001	-3.433312
SUS	13	-45.48346***	0.0001	-3.433312

Note:
All the price series are from March of 2000 to February of 2008
Trend and intercept are added in test at level, apart from only intercept is contained in unit root test of CMXC; and only intercept is added at difference level
BW is the bandwidth chosen by Newey-West automatic truncation lag
#MacKinnon (1996) one-sided p-values.
Asterisks denotes: *** Significant at 1% level; ** Significant at 5% level; * Significant at 10% level

Lag Length for Estimations on Gold

Table X1-03

Lag Length for Estimations on Gold

Variables	SAU	SMX	SUK	SUS
FUS^{CBOT}	6	4	7	4
FUS^{NYMEX}	5	7	4	4
FJP	7	7	7	7
IML	7	7	7	7
ISP	6	7	7	7

Cointegration Results of Pairwised Log Gold Price Series

Table X1- 04

EG's Cointegration tests on
Logarithmic NYMEX Gold Futures Price and Logarithmic Spot Prices of Gold

Variables	ADF Test	PP Test	Conclusion
FUS^{COMEX} and SAU	-45.08477***	-45.20528***	Cointegrated
FUS^{COMEX} and SMX	-8.861375***	-18.39170***	Cointegrated
FUS^{COMEX} and SUK	-28.08397***	-40.47672***	Cointegrated
FUS^{COMEX} and SUS	-43.29869***	-43.29869***	Cointegrated

Notes:
*** Statistically significant at 1% level; ** Statistically significant at 5% level

Table X1- 05

EG's Cointegration tests on
Logarithmic CBOT Gold Futures Price and Logarithmic Spot Prices of Gold

Variables	ADF Test	PP Test	Conclusion
FUS^{CBOT} and SAU	-27.63111***	-27.74941***	Cointegrated
FUS^{CBOT} and SMX	-9.167351***	-8.836990***	Cointegrated
FUS^{CBOT} and SUK	-26.65248***	-26.64451***	Cointegrated
FUS^{CBOT} and SUS	-26.91648***	-26.90572***	Cointegrated

Notes: *** Statistically significant at 1% level; ** Statistically significant at 5% level

Table X1- 06

EG's Cointegration tests on
Logarithmic Merrill Lynch's Gold Index and Logarithmic Spot Prices of Gold

Variables	ADF Test	PP Test	Conclusion
IML and SAU	-6.371248***	-53.78494***	Cointegrated
IML and SMX	-9.131314***	-18.73459***	Cointegrated
IML and SUK	-5.086190***	-46.47543***	Cointegrated
IML and SUS	-5.634722***	-49.58881***	Cointegrated

Notes:
*** Statistically significant at 1% level; ** Statistically significant at 5% level

Table X1- 07

EG's Cointegration tests on
Logarithmic S&P's Gold Index and Logarithmic Spot Prices of Gold

Variables	ADF Test	PP Test	Conclusion
IML and SAU	-13.29851***	-49.62732***	Cointegrated
IML and SMX	-9.089013***	-18.76456***	Cointegrated
IML and SUK	-11.43932***	-44.17681***	Cointegrated
IML and SUS	-12.10727***	-47.78168***	Cointegrated

Notes:
*** Statistically significant at 1% level; ** Statistically significant at 5% level

Table X1- 08

EG's Cointegration tests on
Logarithmic TOCOM Gold Futures Price and Various Logarithmic Spot Prices of Gold

Variables	ADF Test	PP Test	Conclusion
FJP and SAU	-2.3817**	-2.5785***	Cointegrated
FJP and SMX	-4.1611***	-5.8830***	Cointegrated
FJP and SUK	-2.3232**	-2.8959***	Cointegrated
FJP and SUS	-2.3441**	-2.7759***	Cointegrated

Notes:
*** Statistically significant at 1% level; ** Statistically significant at 5% level

Table X1- 09

Johansen's Cointegration tests on
Logarithmic NYMEX Gold Futures Price and Logarithmic Spot Prices of Gold

Price Variables	H_0: rank=r	H_1: rank=r	λ_{trace} Statistics	Critical Values	H_0: rank=r	H_1: rank=r	λ_{max} Statistics	Critical Values
FUS^{COMEX} and SAU	r = 0	r > 0	127.5556*	25.87211	r = 0	r = 1	122.7661*	19.38704
	r ≤ 1	r > 1	4.789453	12.51798	r = 1	r = 2	4.789453	12.51798
FUS^{COMEX} and SMX	r = 0	r > 0	93.17004*	25.87211	r = 0	r = 1	87.31713*	19.38704
	r ≤ 1	r > 1	5.852906	12.51798	r = 1	r = 2	5.852906	12.51798
FUS^{COMEX} and SUK	r = 0	r > 0	334.7471*	25.87211	r = 0	r = 1	329.5531*	19.38704
	r ≤ 1	r > 1	5.193998	12.51798	r = 1	r = 2	5.193998	12.51798
FUS^{COMEX} and SUS	r = 0	r > 0	187.5346*	25.87211	r = 0	r = 1	181.9989*	19.38704
	r ≤ 1	r > 1	5.535664	12.51798	r = 1	r = 2	5.535664	12.51798

Notes:
* denotes rejection of the hypothesis at the 0.05 level
Critical Value is at 5% significant

Table X1- 10

Johansen's Cointegration tests on
Logarithmic CBOT Gold Futures Price and Logarithmic Spot Prices of Gold

Price Variables	H_0: rank=r	H_1: rank=r	λ_{trace} Statistics	Critical Values	H_0: rank=r	H_1: rank=r	λ_{max} Statistics	Critical Values
FUS^{CBOT} and SAU	r = 0	r > 0	127.5556*	25.87211	r = 0	r = 1	122.7661*	19.38704
	r ≤ 1	r > 1	4.789453	12.51798	r = 1	r = 2	4.789453	12.51798
FUS^{CBOT} and SMX	r = 0	r > 0	93.17004*	25.87211	r = 0	r = 1	87.31713*	19.38704
	r ≤ 1	r > 1	5.852906	12.51798	r = 1	r = 2	5.852906	12.51798
FUS^{CBOT} and SUK	r = 0	r > 0	334.7471*	25.87211	r = 0	r = 1	329.5531*	19.38704
	r ≤ 1	r > 1	5.193998	12.51798	r = 1	r = 2	5.193998	12.51798
FUS^{CBOT} and SUS	r = 0	r > 0	187.5346*	25.87211	r = 0	r = 1	181.9989*	19.38704
	r ≤ 1	r > 1	5.535664	12.51798	r = 1	r = 2	5.535664	12.51798

Notes: * denotes rejection of the hypothesis at the 0.05 level
Critical Value is at 5% significant

Table X1- 11

Johansen's Cointegration tests on Logarithmic Merrill Lynch's Gold Index and Logarithmic Spot Prices of Gold

Price Variables	H_0: rank=r	H_1: rank=r	λ_{trace} Statistics	Critical Values	H_0: rank=r	H_1: rank=r	λ_{max} Statistics	Critical Values
IML and SAU	r = 0	r > 0	66.06869*	25.87211	r = 0	r = 1	57.73941*	19.38704
	r ≤ 1	r > 1	8.329280	12.51798	r = 1	r = 2	8.329280	12.51798
IML and SMX	r = 0	r > 0	79.17596*	25.87211	r = 0	r = 1	70.84386*	19.38704
	r ≤ 1	r > 1	8.332105	12.51798	r = 1	r = 2	8.332105	12.51798
IML and SUK	r = 0	r > 0	57.76108*	25.87211	r = 0	r = 1	49.42243*	19.38704
	r ≤ 1	r > 1	8.338649	12.51798	r = 1	r = 2	8.338649	12.51798
IML and	r = 0	r > 0	59.58037*	25.87211	r = 0	r = 1	51.18482*	19.38704

SUS	r ≤ 1	r > 1	8.395553	12.51798	r = 1	r = 2	8.395553	12.51798

Notes:
* denotes rejection of the hypothesis at the 0.05 level
Critical Value is at 5% significant

Table X1- 12

Johansen's Cointegration tests on Logarithmic S&P's Gold Index and Logarithmic Spot Prices of Gold

Price Variables	H_0: rank=r	H_1: rank=r	λ_{trace} Statistics	Critical Values	H_0: rank=r	H_1: rank=r	λ_{max} Statistics	Critical Values
ISP and SAU	r = 0	r > 0	103.7421*	25.87211	r = 0	r = 1	96.05753*	19.38704
	r ≤ 1	r > 1	7.684549	12.51798	r = 1	r = 2	7.684549	12.51798
ISP and SMX	r = 0	r > 0	78.74084*	25.87211	r = 0	r = 1	70.25209*	19.38704
	r ≤ 1	r > 1	8.488756	12.51798	r = 1	r = 2	8.488756	12.51798
ISP and SUK	r = 0	r > 0	94.85535*	25.87211	r = 0	r = 1	86.73393*	19.38704
	r ≤ 1	r > 1	8.121417	12.51798	r = 1	r = 2	8.121417	12.51798
ISP and SUS	r = 0	r > 0	89.19423*	25.87211	r = 0	r = 1	81.01980*	19.38704
	r ≤ 1	r > 1	8.174433	12.51798	r = 1	r = 2	8.174433	12.51798

Notes:
* denotes rejection of the hypothesis at the 0.05 level
Critical Value is at 5% significant

Table X1- 13

Johansen's Cointegration tests on
Logarithmic TOCOM Gold Futures Price and Various Logarithmic Spot Prices of Gold

Price Variables	H_0: rank=r	H_1: rank=r	λ_{trace} Statistics	Critical Values	H_0: rank=r	H_1: rank=r	λ_{max} Statistics	Critical Values
FJP and SAU	r = 0	r > 0	14.9655	25.87211	r = 0	r = 1	10.3491	19.3870
	r ≤ 1	r > 1	4.6164	12.51798	r = 1	r = 2	4.6164	12.5179
FJP and SMX	r = 0	r > 0	22.7836	25.87211	r = 0	r = 1	18.218	19.3870
	r ≤ 1	r > 1	4.5648	12.51798	r = 1	r = 2	4.5648	12.5179
FJP and SUK	r = 0	r > 0	15.4978	25.87211	r = 0	r = 1	10.6651	19.3870
	r ≤ 1	r > 1	4.8326	12.51798	r = 1	r = 2	4.8326	12.5179
FJP and SUS	r = 0	r > 0	15.3134	25.87211	r = 0	r = 1	10.5341	19.3870
	r ≤ 1	r > 1	4.7792	12.51798	r = 1	r = 2	4.7792	12.5179

Notes:
* denotes rejection of the hypothesis at the 0.05 level
Critical Value is at 5% significant

Johansen's Error Correction Estimations on Gold Price Series

Table X1-14 Johansen's VECM on logarithmic CBOT gold futures price and logarithmic gold spot price

Coefficient	FUS	SMX	FUS	SUS	FUS	SAU	FUS	SUK
β	1	-1.027749***	1	-0.998570***	1	-0.999477***	1	-0.999457***
a	-0.010879	0.131518***	-0.296130**	0.639925***	-0.074392	0.877561***	-0.009714	0.828447***
ρ_{11}	0.004648	0.090282***	0.089381	0.038750	0.257658**	0.249884***	-0.017160	0.041121
ρ_{12}	0.006095	0.072911**	0.163105	0.061356	0.206949*	0.098377		
ρ_{13}	0.078479**	0.054005	0.107884	-0.006306	0.260013**	0.041578		
ρ_{14}	0.019812	0.073560**	0.011686	-0.007078	0.164222	0.104519*		
ρ_{15}					0.136507	0.002469		
ρ_{16}					0.033735	-0.021363		
ρ_{21}	-0.029453	-0.121624***	-0.099804	-0.050094	-0.220653*	-0.127212	0.013514	-0.035061
ρ_{22}	-0.011738	-0.065696*	-0.207551**	-0.090753	-0.200535*	-0.050410		
ρ_{23}	-0.017485	-0.027886	0.032576	0.030932	-0.172370*	-0.099326		
ρ_{24}	0.011028	0.002696	-0.011469	0.008485	-0.104833	-0.007146		
ρ_{25}					-0.172635**	-0.022246		
ρ_{26}					-0.038901	0.015885		
R^2	0.005522	0.159588	0.020237	2.003579	0.023170	1.581880	0.000221	0.196315
F-statistic	0.538599	18.41956	0.307257	43.02301	0.616704	107.3044	0.064920	71.81505

Notes

Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level; * Statistically significant at 10% level

Table X1-15 Johansen's VECM on logarithmic NYMEX gold futures price and logarithmic gold spot price

Coefficient	FUS	SMX	FUS	SUS	FUS	SAU	FUS	SUK
β	1	-1.041129***	1	-1.000039***	1	-0.998969***	1	-1.000039***
a	-0.001552	0.120226	-0.178060**	0.713081***	-0.245174***	0.647917***	-0.273218***	0.713081***
ρ_{11}	-0.043872*	0.057771	0.062760	0.126817**	0.137257**	0.243463***	0.107165	0.162607***
ρ_{12}	-0.000378	0.099698**	0.042651	0.054211	0.066396	0.077433*	0.065196	0.036838
ρ_{13}	0.036378	0.084120*	0.035948	-0.009829	0.101040*	0.061914	0.046330	-0.001827
ρ_{14}	0.010303	0.171701***	0.023552	0.019201	0.093752*	0.111439***	0.044774	0.031069
ρ_{15}	-0.006936	0.059285			0.068037*	0.026153		
ρ_{16}	-0.049141**	0.069924						
ρ_{17}	-0.017435	0.065747						
ρ_{21}	0.008944	-0.068351***	-0.059825	-0.101842*	-0.070724	-0.132816***	-0.105472	-0.141113**
ρ_{22}	-0.000321	-0.409636***	-0.031200	-0.033963	-0.048049	-0.067010	-0.047193	-0.013468
ρ_{23}	0.009424	-0.080827***	0.022069	0.011494	-0.073652	-0.100874***	0.010342	0.003482
ρ_{24}	-0.000865	-0.194802***	-0.030320	-0.016037	-0.091159**	-0.047464	-0.044646	-0.028748
ρ_{25}	-0.002855	-0.031320			-0.065317***	-0.027897		
ρ_{26}	-0.017795	-0.068301***						
ρ_{27}	-0.003600	-0.037590*						
R^2	0.008176	0.233403	0.008703	0.311467	0.017090	0.566954	0.013640	0.178607
F-statistic	1.124935	41.54953	2.005640	103.3400	3.245114	244.3485	3.159126	49.67401

Notes

Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level; * Statistically significant at 10% level

Table X1-16 Johansen's VECM on logarithmic Merrill Lynch's gold Index and logarithmic gold spot price

Coefficient	IUS	SMX	IUS	SUS	IUS	SAU	IUS	SUK
β	1	-1.046409***	1	-1.005007***	1	-1.004338***	1	-1.004929***
a	-0.002289	0.126317***	-0.042836	0.128225***	-0.059185	0.140086***	-0.047923	0.104652***
ρ_{11}	-0.043588*	0.065550	-0.036493	0.672369***	-0.027445	0.744224***	-0.081400	0.607194***
ρ_{12}	0.015780	0.075070*	0.016284	0.547787***	-0.027937	0.511020***	-0.036800	0.459372***
ρ_{13}	0.028573	0.085509*	0.022049	0.405347***	0.037488	0.411819***	0.007380	0.341561***
ρ_{14}	0.025822	0.157115***	0.059289	0.380259***	0.081551	0.395464***	0.053351	0.300940***
ρ_{15}	-0.023421	0.061961	0.032061	0.252586***	0.041625	0.224216***	-0.007773	0.182929***
ρ_{16}	-0.052635**	0.063753	0.014942	0.167264***	0.013588	0.131816***	-0.014115	0.111522**
ρ_{17}	-0.010170	0.072799	0.030250	0.102110***	0.033837	0.090318***	0.036173	0.091986***
ρ_{21}	0.011432	-0.061938***	0.015977	-0.623212***	0.058585	-0.586844***	0.069752	-0.574200***
ρ_{22}	-0.002369	-0.402922***	-0.013741	-0.497476***	0.016114	-0.453210***	0.048717	-0.417715***
ρ_{23}	0.010422	-0.075523***	0.021815	-0.376205***	-0.041855	-0.403283***	0.013298	-0.329495***
ρ_{24}	-0.000696	-0.189507***	-0.061947	-0.328462***	-0.066519	-0.269655***	-0.037108	-0.260180***
ρ_{25}	-0.002927	-0.027819	-0.054974	-0.216266***	-0.077904	-0.182174***	-0.006646	-0.165218***
ρ_{26}	-0.020770*	-0.065462***	-0.080553*	-0.162293***	-0.064008	-0.095130***	-0.057233	-0.143864***
ρ_{27}	-0.002348	-0.035204	-0.029652	-0.074417***	-0.022923	-0.010805	-0.052737	-0.064808*
R^2	0.009957	0.233937	0.011446	0.300452	0.014384	0.561417	0.012464	0.178877
F-statistic	1.372409	41.67371	1.580019	58.61168	1.991543	174.6868	1.722395	29.72 847

Notes

Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level; * Statistically significant at 10% level

Table X1-17 Johansen's VECM on logarithmic Standard and Poor's gold Index and logarithmic gold spot price

Coefficient	IUS	SMX	IUS	SUS	IUS	SAU	IUS	SUK
β	1	-1.044274***	1	-1.002899***	1	-1.002023***	1	-1.002831***
a	-0.002040	0.125382***	-0.114635**	0.163780***	-0.121096***	0.192135***	-0.127603***	0.134279***
ρ_{11}	-0.039288*	0.061233	0.031916	0.625549***	0.036870	0.672271***	0.011721	0.548470***
ρ_{12}	0.016284	0.088770**	0.054032	0.468781***	0.013597	0.412463***	0.022730	0.351406***
ρ_{13}	0.032458	0.084211*	0.047899	0.306247***	0.042260	0.308870***	0.006111	0.222077***
ρ_{14}	0.007580	0.161812***	0.052942	0.272250***	0.063593	0.309527***	0.030054	0.198580***
ρ_{15}	-0.012475	0.064315	0.048920	0.186438***	0.053861	0.156680***	0.004214	0.110368**
ρ_{16}	-0.055803**	0.065953	0.009827	0.098207**	-0.001721	0.077101***	-0.020096	0.032779
ρ_{17}	-0.011614	0.072002	0.028932	0.059076*	0.022306	0.055528**	0.033745	0.047743
ρ_{21}	0.008862	-0.064864***	-0.046686	-0.571502***	-0.003543	-0.504114***	-0.023430	-0.509374***
ρ_{22}	-0.000793	-0.405810***	-0.036089	-0.411349***	0.014444	-0.346283***	-0.002065	-0.304540***
ρ_{23}	0.010410	-0.078666***	0.000699	-0.283697***	-0.037821	-0.322701***	0.043079	-0.209176***
ρ_{24}	0.002161	-0.192619***	-0.066897	-0.239517***	-0.071237	-0.198696***	-0.037515	-0.178542***
ρ_{25}	-0.001641	-0.030593	-0.058088	-0.148081***	-0.068606	-0.122490***	-0.005197	-0.087668*
ρ_{26}	-0.018481	-0.067687***	-0.076162	-0.108040***	-0.050362	-0.058133**	-0.049996	-0.077694*
ρ_{27}	-0.001340	-0.037161*	-0.031250	-0.052080*	-0.015822	-0.002400	-0.053233	-0.037219
R^2	0.008728	0.234676	0.011463	0.296770	0.014937	0.552431	0.014215	0.173803
F-statistic	1.201567	41.84571	1.582512	57.59032	2.069297	168.4399	1.967864	28.70788

Notes

Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level; * Statistically significant at 10% level

EG's Error Correction Estimations on Gold Price Series

Table X1-18 EG's VECM on logarithmic CBOT gold futures price and logarithmic gold spot price

Coefficient	FUS	SMX	FUS	SUS	FUS	SAU	FUS	SUK
β	1	-1.031295***	1	-0.999870***	1	-0.999051***	1	-0.999683***
a	-0.464715***	0.519042***	-0.121087	0.879009***	-0.361419***	0.639142***	-0.159502*	0.840771***
ρ_{11}	0.039394	0.038190	0.043182	0.043223	0.252008***	0.252287***	0.036807	0.036809
ρ_{12}	0.024334	0.023602	0.068687	0.068692	0.102599	0.102723		
ρ_{13}			0.001463	0.001455	0.048140	0.048183		
ρ_{14}			-0.005559	-0.005579	0.106894*	0.106996*		
ρ_{15}					0.006365	0.006371		
ρ_{16}					-0.019663	-0.019662		
ρ_{21}	-0.060407**	-0.058578**	-0.053926	-0.053963	-0.130837*	-0.130999*	-0.031212	-0.031223
ρ_{22}	-0.017944	-0.017393	-0.098457	-0.098461	-0.055105	-0.055158		
ρ_{23}			0.030893	0.030898	-0.101761	-0.101867		
ρ_{24}			0.007436	0.007435	-0.009879	-0.009905		
ρ_{25}					-0.025933	-0.025964		
ρ_{26}					0.014845	0.014837		
R^2	0.446243	0.449602	0.321644	0.308453	0.655824	117.8684	0.214579	0.197816
F-statistic	117.9221	119.5351	41.34604	38.89407	0.616978	99.64064	60.17274	54.31309

Notes

Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level; * Statistically significant at 10% level

Table X1-19 EG's VECM on logarithmic NYMEX gold futures price and logarithmic gold spot price

Coefficient	FUS	SMX	FUS	SUS	FUS	SAU	FUS	SUK
β	1	-1.043929***	1	-1.000429	1	-0.999433***	1	-1.000344***
a	-0.157870***	0.806690***	-0.287297***	0.712391***	-0.344153***	0.656224***	-0.430780***	0.569019***
ρ_{11}	-0.024914	-0.023869	0.128535**	0.128470**	0.234961***	0.235092***	0.161196***	0.161151***
ρ_{12}	0.018601	0.017821	0.056711	0.056690	0.079242*	0.079289*	0.041077	0.041066
ρ_{13}	0.045856**	0.043927**	-0.006297	-0.006283	0.068824*	0.068871*	0.003293	0.003291
ρ_{14}	0.040760*	0.039044*	0.020398	0.020381	0.110964***	0.111039***	0.032920	0.032909
ρ_{15}	0.005610	0.005370			0.031947	0.031970		
ρ_{16}	-0.027084	-0.025939						
ρ_{17}	-0.001847	-0.001772						
ρ_{21}	-0.005571	-0.005332	-0.103406*	-0.103362*	-0.128516***	-0.128589***	-0.140731**	-0.140691**
ρ_{22}	-0.076835***	-0.073605***	-0.035885	-0.035878	-0.066927	-0.066957	-0.017666	-0.017657
ρ_{23}	-0.007433	-0.007117	0.010776	0.010780	-0.099081***	-0.099140***	0.003004	0.003001
ρ_{24}	-0.037124***	-0.035559***	-0.016664	-0.016642	-0.053231*	-0.053278*	-0.030261	-0.030248
ρ_{25}	-0.008224	-0.007877			-0.032150*	-0.032168*		
ρ_{26}	-0.027379***	-0.026230***						
ρ_{27}	-0.009973	-0.009555						
R^2	0.157020	0.837855	0.376140	0.311538	0.574010	0.576336	0.270194	0.180269
F-statistic	23.81908	660.7700	123.9006	92.99137	230.4183	232.6220	76.08171	45.19195

Notes

Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level; * Statistically significant at 10% level

Table X1-20 EG's VECM on logarithmic TOCOM gold futures price and logarithmic gold spot price

Coefficient	FJP	SMX	FJP	SUS	FJP	SAU	FJP	SUK
β	1	-1.007839***	1	-0.967557***	1	-0.966776***	1	-0.967430***
a	-0.178538***	0.815073***	-0.476041***	0.541538***	-0.498122***	0.519120***	-0.441212***	0.577603***
ρ_{11}	-0.026662	-0.026443	-0.138649***	-0.143309***	-0.071356***	-0.073802***	-0.161825***	-0.167285***
ρ_{12}	0.057130***	0.056691***	-0.028023	-0.028960	0.041740	0.043196	-0.018427	-0.019056
ρ_{13}	0.030270	0.030035	0.005816	0.006032	0.005078	0.005284	-0.018077	-0.018671
ρ_{14}	0.004475	0.004422	-0.032299	-0.033367	-0.019906	-0.020593	-0.049909**	-0.051568**
ρ_{15}	0.017011	0.016869	-0.013491	-0.013932	-0.024437	-0.025280	-0.013051	-0.013482
ρ_{16}	-0.060280***	-0.059821***	-0.057093***	-0.059014***	-0.053906**	-0.055764**	-0.038154*	-0.039445*
ρ_{17}	-0.006483	-0.006439	-0.027113	-0.028008	-0.016037	-0.016586	-0.014571	-0.015063
ρ_{21}	-0.004536	-0.004501	0.241591***	0.249699***	0.067808***	0.070139***	0.309802	0.320239***
ρ_{22}	-0.074917***	-0.074337***	0.060789***	0.062837***	-0.001783	-0.001861	0.089374***	0.092386***
ρ_{23}	-0.008283	-0.008221	0.020847	0.021541	0.007353	0.007582	0.010941	0.011297
ρ_{24}	-0.041438***	-0.041117***	0.032540	0.033619	0.019043	0.019697	0.056411***	0.058297***
ρ_{25}	-0.004713	-0.004674	-0.004352	-0.004507	-0.003033	-0.003136	-0.001475	-0.001540
ρ_{26}	-0.020649**	-0.020486**	-0.019417	-0.020074	0.008306	0.008590	-0.023155	-0.023932
ρ_{27}	-0.022958**	-0.022779**	0.012967	0.013395	-0.001403	-0.001449	0.011299	0.011674
R^2	0.174920	0.833187	0.377185	0.281853	0.225022	0.194267	0.446214	0.349866
F-statistic	27.11000	638.7042	77.44266	50.18752	37.12961	30.83150	103.0355	68.81525

Notes

Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level; * Statistically significant at 10% level

Table X1-21 EG's VECM on logarithmic Merrill Lynch's gold Index and logarithmic gold spot price

Coefficient	IUS	SMX	IUS	SUS	IUS	SAU	IUS	SUK
β	1	-1.048719***	1	-1.004755***	1	-1.003746***	1	-1.004673***
a	-0.154084***	0.806617***	-0.773410***	0.225501***	-0.737595***	0.261431***	-0.773036***	0.225908***
ρ_{11}	-0.023622	-0.022519	0.591486***	0.588687***	0.629123***	0.626764***	0.510481***	0.508135***
ρ_{12}	0.027073	0.025818	0.487253***	0.484943***	0.430436***	0.428820***	0.389685***	0.387881***
ρ_{13}	0.039518*	0.037688*	0.361656***	0.359950***	0.355887***	0.354554***	0.294639***	0.293280***
ρ_{14}	0.050383**	0.048055**	0.343848***	0.342237***	0.348748***	0.347436***	0.266323***	0.265091***
ρ_{15}	-0.007725	-0.007374	0.227494***	0.226434***	0.196920***	0.196169***	0.156056***	0.155343***
ρ_{16}	-0.031508	-0.030039	0.149904***	0.149201***	0.114069***	0.113629***	0.093772*	0.093334*
ρ_{17}	0.005160	0.004926	0.094002***	0.093563***	0.081892***	0.081578***	0.084255**	0.083851**
ρ_{21}	-0.002089	-0.001997	-0.550367***	-0.547763***	-0.490515***	-0.488665***	-0.483798***	-0.481578***
ρ_{22}	-0.076085***	-0.072554***	-0.442401***	-0.440310***	-0.383150***	-0.381715***	-0.352180***	-0.350540***
ρ_{23}	-0.005356	-0.005115	-0.330750***	-0.329194***	-0.349489***	-0.348166***	-0.281358***	-0.280060***
ρ_{24}	-0.035442***	-0.033798***	-0.298293***	-0.296900***	-0.239459***	-0.238559***	-0.228967***	-0.227908***
ρ_{25}	-0.007557	-0.007210	-0.198051***	-0.197117***	-0.166752***	-0.166119***	-0.142927***	-0.142276***
ρ_{26}	-0.029177***	-0.027822***	-0.153248***	-0.152542***	-0.090597***	-0.090256***	-0.131881***	-0.131266***
ρ_{27}	-0.008408	-0.008014	-0.069447***	-0.069131***	-0.012701	-0.012642	-0.063278*	-0.062980*
R^2	0.159622	0.845240	0.342522	0.306633	0.556060	0.577709	0.241532	0.185746
F-statistic	24.28872	698.4018	66.61811	56.55117	160.1705	174.9377	40.72137	29.17054

Notes

Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level; * Statistically significant at 10% level

Table X1-22 EG's VECM on logarithmic Standard and Poor's gold Index and logarithmic gold spot price

Coefficient	IUS	SMX	IUS	SUS	IUS	SAU	IUS	SUK
β	1	-1.046637***	1	-1.002771***	1	-1.001760***	1	-1.002831***
a	-0.154947***	0.807402***	-0.761542***	0.237843***	-0.688494***	0.310945***	-0.127603***	0.134279***
ρ_{11}	-0.020788	-0.019867	0.565955***	0.564351***	0.560325***	0.559359***	0.011721	0.548470***
ρ_{12}	0.030047	0.028712	0.427171***	0.425936***	0.334817***	0.334243***	0.022730	0.351406***
ρ_{13}	0.042510**	0.040611**	0.280276***	0.279459***	0.246851***	0.246429***	0.006111	0.222077***
ρ_{14}	0.036298*	0.034680*	0.250245***	0.249520***	0.246111***	0.245687***	0.030054	0.198580***
ρ_{15}	0.001788	0.001708	0.172633***	0.172133***	0.114005***	0.113816***	0.004214	0.110368**
ρ_{16}	-0.033621	-0.032115	0.089263**	0.089003**	0.031191	0.031147	-0.020096	0.032779
ρ_{17}	0.003881	0.003709	0.056048*	0.055896*			0.033745	0.047743
ρ_{21}	-0.004799	-0.004586	-0.518869***	-0.517389***	-0.411880***	-0.411166***	-0.023430	-0.509374***
ρ_{22}	-0.075582***	-0.072217***	-0.373684***	-0.372598***	-0.272170***	-0.271709***	-0.002065	-0.304540***
ρ_{23}	-0.006005	-0.005743	-0.255058***	-0.254315***	-0.252372***	-0.251938***	0.043079	-0.209176***
ρ_{24}	-0.033786***	-0.032280***	-0.222260***	-0.221609***	-0.153062***	-0.152793***	-0.037515	-0.178542***
ρ_{25}	-0.007023	-0.006714	-0.139091***	-0.138684***	-0.083398***	-0.083266***	-0.005197	-0.087668*
ρ_{26}	-0.027723***	-0.026490***	-0.104947***	-0.104649***	-0.013739	-0.013726	-0.049996	-0.077694*
ρ_{27}	-0.007957	-0.007606	-0.050057*	-0.049913*			-0.053233	-0.037219
R^2	0.155533	0.840689	0.353522	0.301589	0.558737	0.569216	0.014215	0.173803
F-statistic	23.55180	674.8017	69.92748	55.21922	185.3207	193.3887	1.967864	28.70788

Notes

Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level; * Statistically significant at 10% level

Table X1-23

Pairwised Granger Causality Tests of Gold
Sample: 3/24/2000 2/29/2008

Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.	Decision
SAU does not Granger Cause FJP^{TOCOM}	2069	43.9554***	2.E-19	False
FJP^{TOCOM} does not Granger Cause SAU		5.51868***	0.0041	False
SMX does not Granger Cause FJP^{TOCOM}	2069	1.33130	0.2644	True
FJP^{TOCOM} does not Granger Cause SMX		31.3000***	4.E-14	False
SUK does not Granger Cause FJP^{TOCOM}	2069	318.526***	3E-121	False
FJP^{TOCOM} does not Granger Cause SUK		2.92688***	0.0538	False
SUS does not Granger Cause FJP^{TOCOM}	2069	192.418***	2.E-77	False
FJP^{TOCOM} does not Granger Cause SUS		3.85667***	0.0213	False

Appendix II

Unit Root Tests Results for Price Series of Silver

Table X2-01

Augmented Dickey-Fuller (ADF) Unit Root Tests for Various logarithmic Prices of Silver

Panel a	Level (lnP)			
Variable	Lag Length	ADF Test Statistic	Prob.#	Critical Value at 10%
FUS^{CBOT}	0	-1.997912	0.6012	-3.129619
FUS^{COMEX}	0	-2.345426	0.4085	-3.127895
FJP	0	-2.200781	0.4883	-3.127895
IML	0	-2.273338	0.4479	-3.127895
ISP	0	-2.345619	0.4084	-3.127895
SAU	1	-2.216739	0.4794	-3.127895
SMX	4	-2.709333	0.2328	-3.127897
SUK	0	-2.169555	0.5059	-3.127895
SUS	0	-2.190815	0.4939	-3.127895
Panel b	First difference (ΔlnP)			
Variable	Lag Length	ADF Test Statistic	Prob.#	Critical Value at 1%
FUS^{CBOT}	0	-30.00076***	0.0000	-3.437508
FUS^{COMEX}	0	-47.38118***	0.0001	-3.433312
FJP	0	-48.24171***	0.0001	-3.433312
IML	0	-47.42602***	0.0001	-3.433312
ISP	0	-47.23883***	0.0001	-3.433312
SAU	0	-48.74022***	0.0001	-3.433312
SMX	3	-32.78424***	0.0000	-3.433317
SUK	0	-45.80762***	0.0001	-3.433312
SUS	0	-45.48171***	0.0001	-3.433312

Note:
All the estimated price series are from March of 2000 to February of 2008
Trend and intercept are added in test at level; and only intercept is added at difference level
Optimal lag lengths chosen by Schwarz Info Criterion (SIC)
Asymptotic critical values are from Davidson and Mackinnon (1993)
#MacKinnon (1996) one-sided p-values.
Asterisks denotes: *** Significant at 1% level; ** Significant at 5% level; * Significant at 10% level

Table X2-02

Phillip-Perron (PP) Unit Root Tests for Various logarithmic Prices of Silver

Panel a		Level (lnP)		
Variable	BW	PP Test Statistic	Prob.#	Critical Value at 10%
FUS^{CBOT}	9	-2.624155	0.2695	-3.129619
FUS^{COMEX}	8	-2.269022	0.4503	-3.127895
FJP	4	-2.107774	0.5406	-3.127895
IML	7	-2.266247	0.4518	-3.127895
ISP	7	-2.246021	0.4630	-3.127895
SAU	6	-2.221974	0.4765	-3.127895
SMX	18	-2.527061	0.3148	-3.127895
SUK	5	-2.259137	0.4557	-3.127895
SUS	7	-2.221103	0.4770	-3.127895
Panel b		First difference (ΔlnP)		
Variable	BW	PP Test Statistic	Prob.#	Critical Value at 1%
FUS^{CBOT}	11	-30.62715***	0.0000	-3.437508
FUS^{COMEX}	8	-46.69318***	0.0001	-3.433312
FJP	5	-44.98861***	0.0001	-3.433312
IML	6	-46.61070***	0.0001	-3.433312
ISP	7	-46.74739***	0.0001	-3.433312
SAU	5	-45.42570***	0.0001	-3.433312
SMX	20	-47.44754***	0.0001	-3.433312
SUK	5	-47.92655***	0.0001	-3.433312
SUS	7	-46.05718***	0.0001	-3.433312

Note:

All the price series are from March of 2000 to February of 2008

Trend and intercept are added in test at level, apart from only intercept is contained in unit root test of CMXC; and only intercept is added at difference level

BW is the bandwidth chosen by Newey-West automatic truncation lag

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

Asterisks denotes: *** Significant at 1% level; ** Significant at 5% level; * Significant at 10% level

Lag Length for Estimations on Silver

Table X2-03

Lag Length for Estimations on Silver

Variables	SAU	SMX	SUK	SUS
FUS^{CBOT}	5	6	4	6
FUS^{NYMEX}	6	5	6	3
FJP	4	6	4	5
IML	7	5	6	5
ISP	7	6	6	5

Cointegration Results of Pairwised Log Silver Price Series

Table X2- 04

EG's Cointegration tests on
Logarithmic NYMEX Silver Futures Price and Logarithmic Spot Prices of Silver

Variables	ADF Test	PP Test	Conclusion
FUS^{COMEX} and SAU	-21.72980***	-44.54586***	Cointegrated
FUS^{COMEX} and SMX	-6.303997***	-7.656096***	Cointegrated
FUS^{COMEX} and SUK	-21.92780***	-45.23206***	Cointegrated
FUS^{COMEX} and SUS	-40.33236***	-41.93831***	Cointegrated

Notes:
*** Statistically significant at 1% level; ** Statistically significant at 5% level

Table X2- 05

EG's Cointegration tests on
Logarithmic CBOT Silver Futures Price and Logarithmic Spot Prices of Silver

Variables	ADF Test	PP Test	Conclusion
FUS^{CBOT} and SAU	-18.85366***	-28.63319***	Cointegrated
FUS^{CBOT} and SMX	-10.31405***	-10.17573***	Cointegrated
FUS^{CBOT} and SUK	-29.95680***	-29.98771***	Cointegrated
FUS^{CBOT} and SUS	-26.95605***	-27.01308***	Cointegrated

Notes: *** Statistically significant at 1% level; ** Statistically significant at 5% level

Table X2- 06

EG's Cointegration tests on
Logarithmic Merrill Lynch's Silver Index and Logarithmic Spot Prices of Silver

Variables	ADF Test	PP Test	Conclusion
IML and SAU	-23.20881***	-56.80468***	Cointegrated
IML and SMX	-6.166820***	-7.468879***	Cointegrated
IML and SUK	-9.638474***	-47.49128***	Cointegrated
IML and SUS	-7.948076***	-48.08393***	Cointegrated

Notes:
*** Statistically significant at 1% level; ** Statistically significant at 5% level

Table X2- 07

EG's Cointegration tests on
Logarithmic S&P's Silver Index and Logarithmic Spot Prices of Silver

Variables	ADF Test	PP Test	Conclusion
IML and SAU	-46.37956***	-20.74380***	Cointegrated
IML and SMX	-21.15677***	-46.22105***	Cointegrated
IML and SUK	-6.166958***	-7.492043***	Cointegrated
IML and SUS	-13.45009***	-44.49967***	Cointegrated

Notes:
*** Statistically significant at 1% level; ** Statistically significant at 5% level

Table X2- 08

EG's Cointegration tests on
Logarithmic TOCOM Silver Futures Price and Various Logarithmic Spot Prices of Silver

Variables	ADF Test	PP Test	Conclusion
FJP and SAU	-3.033096***	-3.538419***	Cointegrated
FJP and SMX	-5.974697***	-6.862049***	Cointegrated
FJP and SUK	-3.040098***	-5.119751***	Cointegrated
FJP and SUS	-3.100410***	-5.340810***	Cointegrated

Notes:
*** Statistically significant at 1% level; ** Statistically significant at 5% level

Table X2- 09

Johansen's Cointegration tests on
Logarithmic NYMEX Silver Futures Price and Logarithmic Spot Prices of Silver

Price Variables	H_0: rank=r	H_1: rank=r	λ_{trace} Statistics	Critical Values	H_0: rank=r	H_1: rank=r	λ_{max} Statistics	Critical Values
FUS^{COMEX}and	r = 0	r > 0	166.0307*	25.87211	r = 0	r = 1	157.9815*	19.38704
SAU	r ≤ 1	r > 1	8.049248	12.51798	r = 1	r = 2	8.049248	12.51798
FUS^{COMEX}and	r = 0	r > 0	64.56376*	25.87211	r = 0	r = 1	56.67619*	19.38704
SMX	r ≤ 1	r > 1	7.887566	12.51798	r = 1	r = 2	7.887566	12.51798
FUS^{COMEX}and	r = 0	r > 0	196.2799*	25.87211	r = 0	r = 1	188.1556*	19.38704
SUK	r ≤ 1	r > 1	8.124309	12.51798	r = 1	r = 2	8.124309	12.51798
FUS^{COMEX}and	r = 0	r > 0	385.3443*	25.87211	r = 0	r = 1	377.5793*	19.38704
SUS	r ≤ 1	r > 1	7.765006	12.51798	r = 1	r = 2	7.765006	12.51798

Notes:
* denotes rejection of the hypothesis at the 0.05 level
Critical Value is at 5% significant

Table X2- 10

Johansen's Cointegration tests on
Logarithmic CBOT Silver Futures Price and Logarithmic Spot Prices of Silver

Price Variables	H_0: rank=r	H_1: rank=r	λ_{trace} Statistics	Critical Values	H_0: rank=r	H_1: rank=r	λ_{max} Statistics	Critical Values
FUS^{CBOT}and	r = 0	r > 0	132.3226*	25.87211	r = 0	r = 1	126.8276*	19.38704
SAU	r ≤ 1	r > 1	5.495022	12.51798	r = 1	r = 2	5.495022	12.51798
FUS^{CBOT}and	r = 0	r > 0	144.4822*	25.87211	r = 0	r = 1	137.2524*	19.38704
SMX	r ≤ 1	r > 1	7.229821	12.51798	r = 1	r = 2	7.229821	12.51798
FUS^{CBOT} and	r = 0	r > 0	184.4442*	25.87211	r = 0	r = 1	177.7886*	19.38704
SUK	r ≤ 1	r > 1	6.655628	12.51798	r = 1	r = 2	6.655628	12.51798
FUS^{CBOT} and	r = 0	r > 0	327.1236*	25.87211	r = 0	r = 1	319.9671*	19.38704
SUS	r ≤ 1	r > 1	7.156474	12.51798	r = 1	r = 2	7.156474	12.51798

Notes: * denotes rejection of the hypothesis at the 0.05 level
Critical Value is at 5% significant

Table X2- 11

Johansen's Cointegration tests on Logarithmic Merrill Lynch's Silver Index and Logarithmic Spot Prices of Silver

Price Variables	H_0: rank=r	H_1: rank=r	λ_{trace} Statistics	Critical Values	H_0: rank=r	H_1: rank=r	λ_{max} Statistics	Critical Values
IML and	r = 0	r > 0	100.9586*	25.87211	r = 0	r = 1	92.50645*	19.38704
SAU	r ≤ 1	r > 1	8.452126	12.51798	r = 1	r = 2	8.452126	12.51798

IML and SMX	r = 0	r > 0	63.32359*	25.87211	r = 0	r = 1	55.38697*	19.38704
	r ≤ 1	r > 1	7.936620	12.51798	r = 1	r = 2	7.936620	12.51798
IML and SUK	r = 0	r > 0	151.1503*	25.87211	r = 0	r = 1	143.0487*	19.38704
	r ≤ 1	r > 1	8.101589	12.51798	r = 1	r = 2	8.101589	12.51798
IML and SUS	r = 0	r > 0	154.5687*	25.87211	r = 0	r = 1	146.4339*	19.38704
	r ≤ 1	r > 1	8.134784	12.51798	r = 1	r = 2	8.134784	12.51798

Notes:
* denotes rejection of the hypothesis at the 0.05 level
Critical Value is at 5% significant

Table X2- 12

Johansen's Cointegration tests on Logarithmic S&P's Silver Index and Logarithmic Spot Prices of Silver

Price Variables	H_0: rank=r	H_1: rank=r	λ_{trace} Statistics	Critical Values	H_0: rank=r	H_1: rank=r	λ_{max} Statistics	Critical Values
ISP and SAU	r = 0	r > 0	116.2361*	25.87211	r = 0	r = 1	107.8360*	19.38704
	r ≤ 1	r > 1	8.400118	12.51798	r = 1	r = 2	8.400118	12.51798
ISP and SMX	r = 0	r > 0	58.61712*	25.87211	r = 0	r = 1	50.69322*	19.38704
	r ≤ 1	r > 1	7.923898	12.51798	r = 1	r = 2	7.923898	12.51798
ISP and SUK	r = 0	r > 0	167.0549*	25.87211	r = 0	r = 1	158.9661*	19.38704
	r ≤ 1	r > 1	8.088810	12.51798	r = 1	r = 2	8.088810	12.51798
ISP and SUS	r = 0	r > 0	168.0146*	19.38704	r = 0	r = 1	168.0146*	19.38704
	r ≤ 1	r > 1	8.040238	12.51798	r = 1	r = 2	8.040238	12.51798

Notes:
* denotes rejection of the hypothesis at the 0.05 level
Critical Value is at 5% significant

Table X2- 13

Johansen's Cointegration tests on
Logarithmic TOCOM Silver Futures Price and Various Logarithmic Spot Prices of Silver

Price Variables	H_0: rank=r	H_1: rank=r	λ_{trace} Statistics	Critical Values	H_0: rank=r	H_1: rank=r	λ_{max} Statistics	Critical Values
FJP and SAU	r = 0	r > 0	16.17790	25.87211	r = 0	r = 1	9.700585	19.38704
	r ≤ 1	r > 1	6.477311	12.51798	r = 1	r = 2	6.477311	12.51798
FJP and SMX	r = 0	r > 0	56.28178*	25.87211	r = 0	r = 1	49.93364*	19.38704
	r ≤ 1	r > 1	6.348148	12.51798	r = 1	r = 2	6.348148	12.51798
FJP and SUK	r = 0	r > 0	16.05028	25.87211	r = 0	r = 1	9.652946	19.38704
	r ≤ 1	r > 1	6.397332	12.51798	r = 1	r = 2	6.397332	12.51798
FJP and SUS	r = 0	r > 0	15.85122	25.87211	r = 0	r = 1	9.968307	19.38704
	r ≤ 1	r > 1	5.882916	12.51798	r = 1	r = 2	5.882916	12.51798

Notes:
* denotes rejection of the hypothesis at the 0.05 level
Critical Value is at 5% significant

Johansen's Error Correction Estimations on Silver Price Series

Table X2-14 Johansen's VECM on logarithmic CBOT Silver futures price and logarithmic Silver spot price

Coefficient	FUS	SMX	FUS	SUS	FUS	SAU	FUS	SUK
β	1	-1.181208***	1	-1.001572***	1	-0.996801***	1	-0.996865***
a	-0.017154	0.151004***	-0.145590	0.728119***	-0.356104***	0.552025***	-0.246868*	0.803787***
ρ_{11}	-0.017543	0.026316	0.068100	0.095954	0.297442**	0.354516***	0.228254*	0.197470***
ρ_{12}	0.056920	0.043112	0.049841	0.032270	0.303529**	0.191997***	0.348088***	0.077964
ρ_{13}	0.039404	0.014051	-0.000100	-0.035208	0.356963***	0.141332***	0.331276***	0.089819
ρ_{14}	-0.018429	0.030492	-0.022566	0.012219	0.192959*	0.155833***	0.147864**	0.085324**
ρ_{15}	-0.074431*	-0.014291	-0.029193	-0.027224	0.027352	0.019774		
ρ_{16}	0.005493	0.047214*	-0.156998*	-0.150872*				
ρ_{21}	-0.005431	-0.016160	-0.092225	-0.104618	-0.246970*	-0.219685***	-0.303189***	-0.125499*
ρ_{22}	-0.062848	-0.087524**	-0.002626	-0.006726	-0.361597***	-0.202543***	-0.335615***	-0.152819***
ρ_{23}	0.037101	-0.074842*	0.036198	0.036577	-0.257939***	-0.181164***	-0.239854***	-0.124504***
ρ_{24}	0.048118	-0.010364	0.002070	-0.027213	-0.021195	-0.020808	-0.034075	-0.008646
ρ_{25}	-0.027352	-0.040040	0.023044	0.004981	-0.089484**	-0.025173		
ρ_{26}	-0.007106	0.056456*	0.188059**	0.171820**				
R^2	0.019026	0.189855	0.020854	0.134792	0.026769	0.750214	0.018016	0.692949
F-statistic	0.982297	11.86898	1.078668	7.890357	2.175439	237.5437	1.779656	218.9089

Notes

Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level; * Statistically significant at 10% level

Table X2-15 Johansen's VECM on logarithmic NYMEX Silver futures price and logarithmic Silver spot price

Coefficient	FUS	SMX	FUS	SUS	FUS	SAU	FUS	SUK
β	1	-1.148167***	1	-1.003931***	1	-1.000944***	1	-0.999468***
a	-0.014898***	0.032466***	-0.185562***	0.581026***	-0.204543***	0.374304***	-0.159882**	0.488503***
ρ_{11}	0.177590***	0.094616***	-0.112894**	0.198277***	0.156558**	0.528097***	0.132778*	0.471381***
ρ_{12}	0.032475	0.083831***	0.037763	0.100904	0.166100**	0.311537***	0.222938***	0.270408***
ρ_{13}	0.031129	0.071876***	-0.091611*	0.031905	0.235607***	0.240774***	0.268287***	0.245993***
ρ_{14}	-0.101522*	0.086761***			0.160849***	0.238396***	0.182029***	0.193275***
ρ_{15}	0.105759**	0.059034***			0.088365	0.111263***	0.071696	0.106325***
ρ_{16}					0.020515	0.058622***	-0.035214	0.011315
ρ_{21}	-0.021016	-0.076494***	-0.085593	-0.200291***	-0.121557	-0.360155***	-0.181250***	-0.336398***
ρ_{22}	-0.004021	-0.130934***	0.000454	-0.066259	-0.226402***	-0.293786***	-0.252609***	-0.305931***
ρ_{23}	0.005944	-0.100689***	0.005141	-0.028755	-0.175101***	-0.254024***	-0.216428***	-0.237497***
ρ_{24}	-0.016041	-0.073568***			-0.082857	-0.124923***	-0.091691	-0.114158***
ρ_{25}	-0.006766	-0.023034			-0.052816	-0.063388**	0.015334	-0.029636
ρ_{26}					0.000246	-0.004979	0.007208	0.002254
R^2	0.004978	0.082249	0.005046	0.130599	0.010471	0.724313	0.013232	0.683300
F-statistic	0.933700	16.72631	1.491663	44.18524	1.668616	414.3062	2.114590	340.2304

Notes

Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level; * Statistically significant at 10% level

Table X2-16 Johansen’s VECM on logarithmic Merrill Lynch’s Silver Index and logarithmic Silver spot price

Coefficient	IUS	SMX	IUS	SUS	IUS	SAU	IUS	SUK
β	1	-1.152529***	1	-1.007699***	1	-1.005026***	1	-1.003347***
a	-0.014344**	0.030754***	-0.117204	0.247552***	-0.103355*	0.216406***	-0.103991*	0.320206***
ρ_{11}	-0.013882	0.091420***	0.177489***	0.501790***	0.059138	0.684105***	0.082772	0.634370***
ρ_{1}	-0.183411***	0.095925***	0.026589	0.361539***	0.072869	0.438962***	0.185463***	0.403845***
ρ_{13}	0.023687	0.075585***	-0.101509	0.242277***	0.140794**	0.355205***	0.226812***	0.356821***
ρ_{14}	-0.115517**	0.090412***	0.055687***	0.207377***	0.094920	0.338667***	0.173014***	0.285066***
ρ_{15}	-0.153308***	0.056404***	0.049536	0.058308	0.007105	0.181797***	0.052365	0.164041***
ρ_{16}					-0.053518	0.112592***	-0.047487	0.042541
ρ_{17}					-0.081647*	0.030248		
ρ_{21}	-0.013625	-0.077589***	-0.047994	-0.492092***	-0.023718	-0.490053***	-0.138450**	-0.474789***
ρ_{22}	-0.003038	-0.133529***	0.009753	-0.316234***	-0.130342*	-0.410973***	-0.212336***	-0.420265***
ρ_{23}	0.005261	-0.101281***	-0.008654	-0.237130***	-0.099104	-0.354829***	-0.198134***	-0.328244***
ρ_{24}	-0.015275	-0.072808***	-0.048738	-0.171932***	-0.007743	-0.196446***	-0.078975	-0.175438***
ρ_{25}	-0.003313	-0.022816	-0.037828	-0.054268	0.017792	-0.116214***	0.026175	-0.062732**
ρ_{26}					0.082372	-0.035233	0.010647	-0.001169
ρ_{27}					-0.030331	0.003669		
R^2	0.004649	0.082870	0.004572	0.130735	0.013013	1.799302	0.012663	0.677701
F-statistic	0.871812	16.86404	0.857183	28.06968	0.722323	354.9919	2.022432	331.5816

Notes

Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level; * Statistically significant at 10% level

Table X2-17 Johansen's VECM on logarithmic Standard and Poor's Silver Index and logarithmic Silver spot price

Coefficient	IUS	SMX	IUS	SUS	IUS	SAU	IUS	SUK
β	1	-1.153728***	1	-1.006263***	1	1	1	-1.001892***
a	-0.013608**	0.029808***	-0.138908*	0.295687***	-0.114221*	-0.114221*	-0.120110*	0.378622***
ρ_{11}	-0.016259	0.099355***	0.051216	0.441292***	0.066727	0.634266***	0.094603	0.580102***
ρ_{12}	0.105754**	0.088947***	0.176728***	0.293077***	0.074095	0.389752***	0.190052***	0.350721***
ρ_{13}	0.030103	0.074580***	0.029055	0.185426***	0.136163*	0.305215***	0.237145***	0.308966***
ρ_{14}	-0.112875**	0.090574***	-0.101187*	0.135860**	0.064897	0.295246***	0.159583***	0.244926***
ρ_{15}	0.025717	0.064026***	0.105730**	0.053305	0.011039	0.155595***	0.062006	0.146893***
ρ_{16}	-0.091206*	0.039941***			-0.066913	0.084922***	-0.048172	0.026655
ρ_{17}					-0.100983**	0.012119		
ρ_{21}	-0.019398	-0.081933***	-0.068495	-0.431773***	-0.032358	-0.439370***	-0.147930**	-0.420025***
ρ_{22}	-0.003047	-0.136429***	0.004427	-0.246530***	-0.124223	-0.354874***	-0.219478***	-0.367608***
ρ_{23}	0.005970	-0.104600***	-0.008628	-0.174544***	-0.072381	-0.308698***	-0.193111***	-0.285666***
ρ_{24}	-0.013873	-0.077170***	-0.034403	-0.110795*	-0.004211	-0.165798***	-0.079957	-0.149583***
ρ_{25}	-0.003078	-0.028510	-0.050801	-0.048922	0.027849	-0.088274***	0.024974	-0.046342
ρ_{26}	-0.006671	0.016795			0.101927**	-0.015161	0.012651	0.003247
ρ_{27}					-0.028754	0.005702		
R^2	0.005577	0.084941	0.005360	0.123042	0.013594	0.722276	0.012506	0.680294
F-statistic	0.884459	14.63782	1.005853	26.18600	1.880751	354.9083	1.997138	335.5501

Notes

Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level; * Statistically significant at 10% level

EG's Error Correction Estimations on Silver Price Series

Table X2-18 EG's VECM on logarithmic CBOT Silver futures price and logarithmic Silver spot price

Coefficient	FUS	SMX	FUS	SUS	FUS	SAU	FUS	SUK
β	1	-1.175521***	1	-1.001566***	1	-0.996864***	1	-0.996558***
a	0.431305***	-0.492993***	-0.260638	0.738178***	-0.450375***	0.551341***	-0.200675***	0.802095***
ρ_{11}	0.018302	0.015562	0.093851	0.093719	0.353784***	0.354914***	0.198024***	0.198708***
ρ_{12}	0.056171**	0.047774**	0.033711	0.033703	0.190527***	0.191135***	0.085290	0.085585
ρ_{13}	0.032742	0.027855	-0.032451	-0.032357	0.139237***	0.139687***	0.096271*	0.096592*
ρ_{14}	0.018019	0.015328	0.009390	0.009432	0.155060***	0.155531***	0.086841**	0.087138**
ρ_{15}	0.020848	0.017733	-0.103105	-0.102929	0.019653	0.019707		
ρ_{16}	-0.034351	-0.029232	-0.151603*	-0.151342*				
ρ_{21}	-0.023432	-0.019930	-0.103786	-0.103631	-0.218734***	-0.219423***	-0.130417**	-0.130862**
ρ_{22}	-0.092858**	-0.078989***	-0.006386	-0.006419	-0.200639***	-0.201290***	-0.157716***	-0.158253***
ρ_{23}	-0.043549	-0.037055	0.036624	0.036520	-0.179985***	-0.180535***	-0.127538***	-0.127965***
ρ_{24}	0.008926	0.007594	-0.024855	-0.024870	-0.020716	-0.020765	-0.009513	-0.009538
ρ_{25}	-0.046635	-0.039665	0.068009	0.067884	-0.024587	-0.024662		
ρ_{26}	0.028797	0.024500	0.173385**	0.173101**				
R^2	0.447958	0.497735	0.161625	0.135909	0.786350	0.750264	0.677383	0.693400
F-statistic	50.19433	61.29921	9.210807	7.514753	266.5331	217.5563	183.0894	197.2097

Notes

Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level; * Statistically significant at 10% level

Table X2-19 EG's VECM on logarithmic NYMEX Silver futures price and logarithmic Silver spot price

Coefficient	FUS	SMX	FUS	SUS	FUS	SAU	FUS	SUK
β	1	-1.146981***	1	-1.004138***	1	-1.001589***	1	-1.000034***
a	-0.469662***	0.462380***	-0.404433***	0.593135***	0.387525***	-0.611856***	-0.481939***	0.518051***
ρ_{11}	0.044548***	0.038835***	0.192898***	0.192092***	0.517409***	0.516589***	0.442977***	0.442951***
ρ_{12}	0.062999***	0.054923***	0.098313	0.097893	0.308351***	0.307856***	0.267744***	0.267726***
ρ_{13}	0.055720***	0.048580***	0.031718	0.031590	0.242242***	0.241857***	0.249234***	0.249221***
ρ_{14}	0.055254***	0.048176***			0.236867***	0.236487***	0.193145***	0.193140***
ρ_{15}	0.045276***	0.039479***			0.111201***	0.111029***	0.103790***	0.103787***
ρ_{16}					0.057653***	0.057565***	0.007445	0.007456
ρ_{21}	-0.053022***	-0.046226***	-0.195204***	-0.194388***	-0.353423***	-0.352858***	-0.323851***	-0.323832***
ρ_{22}	-0.074142***	-0.064645***	-0.063098	-0.062832	-0.292820***	-0.292356***	-0.302133***	-0.302121***
ρ_{23}	-0.052320***	-0.045616***	-0.027027	-0.026916	-0.252209***	-0.251802***	-0.236212***	-0.236213***
ρ_{24}	-0.048833***	-0.042578***			-0.123913***	-0.123715***	-0.112418***	-0.112417***
ρ_{25}	-0.016204	-0.014126			-0.063164**	-0.063073**	-0.025632	-0.025641
ρ_{26}					-0.004543	-0.004534	0.002933	0.002929
R^2	0.421904	0.503313	0.181602	0.131217	0.725363	0.748384	0.664069	0.689050
F-statistic	124.7989	173.2813	57.08362	38.85394	386.5546	435.3127	289.3187	324.3208

Notes

Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level; * Statistically significant at 10% level

Table X2-20 EG's VECM on logarithmic TOCOM Silver futures price and logarithmic Silver spot price

Coefficient	FJP	SMX	FJP	SUS	FJP	SAU	FJP	SUK
β	1	-1.126672***	1	-0.978340***	1	-0.976974***	1	
a	-0.011850**	0.027086***	-0.244169***	0.772564***	-0.306474***	0.709881***	-0.211053***	-0.975354***
ρ_{11}	0.009755	0.138281***	-0.240310***	-0.245641***	-0.166113***	-0.170027***	-0.192370***	0.808876***
ρ_{12}	0.066824***	0.088058***	-0.057104***	-0.058370***	0.035605	0.036443	0.025274	-0.197224***
ρ_{13}	0.040024*	0.089353***	-0.039796	-0.040680*	0.029622	0.030321	0.008721	0.025924
ρ_{14}	0.028201	0.030813	-0.024932	-0.025484	0.030634	0.031354	0.017125	0.008944
ρ_{15}	-0.037674	0.038667	-0.026485	-0.027072				0.017558
ρ_{16}	-0.012428	0.024260						
ρ_{21}	0.045769**	-0.070183***	0.455147***	0.465224***	0.213314***	0.218345***	0.239124***	0.245162***
ρ_{22}	0.005343	-0.133595***	0.192112***	0.196376***	0.035762	0.036610	0.050759*	0.052030*
ρ_{23}	-0.002617	-0.099148***	0.074777***	0.076434***	0.008361	0.008563	0.046400*	0.047566*
ρ_{24}	0.008507	-0.068377***	0.084457***	0.086326***	-0.004984	-0.005100	0.004378	0.004484
ρ_{25}	-0.028980	-0.026245	0.018735	0.019146				
ρ_{26}	-0.006355	0.021800						
R^2	0.015759	0.071944	0.505125	0.591602	0.125192	0.259800	0.131148	0.376667
F-statistic	2.524894	12.22446	174.5419	247.7089	29.40873	72.12758	31.01894	0.013660

Notes

Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level; * Statistically significant at 10% level

Table X2-21 EG's VECM on logarithmic Merrill Lynch's Silver Index and logarithmic Silver spot price

Coefficient	IUS	SMX	IUS	SUS	IUS	SAU	IUS	SUK
β	1	-1.150879***	1	-1.007923***	1	-1.005367***	1	-1.003814***
a	-0.465288***	0.464603***	0.327556***	-0.669860***	0.248341***	-0.750308***	0.380218***	-0.618328***
ρ_{11}	0.042594***	0.037013***	0.445777***	0.442259***	0.658076***	0.654579***	0.578724***	0.576526***
ρ_{12}	0.070638***	0.061385***	0.321523***	0.318979***	0.424032***	0.421787***	0.382680***	0.381231***
ρ_{13}	0.053690***	0.046656***	0.216057***	0.214349***	0.347065***	0.345224***	0.344732***	0.343432***
ρ_{14}	0.060856***	0.052872***	0.189579***	0.188102***	0.328947***	0.327206***	0.274468***	0.273454***
ρ_{15}	0.040459**	0.035157***	0.057731	0.057285	0.174512***	0.173593***	0.152940***	0.152384***
ρ_{16}					0.105304***	0.104748***	0.033235	0.033120
ρ_{17}					0.025101	0.024960		
ρ_{21}	-0.049520***	-0.043039***	-0.439005***	-0.435539***	-0.470485***	-0.467999***	-0.441191***	-0.439527***
ρ_{22}	-0.074517***	-0.064759***	-0.276977***	-0.274783***	-0.399856***	-0.397736***	-0.399967***	-0.398459***
ρ_{23}	-0.052550***	-0.045668***	-0.209732***	-0.208075***	-0.344545***	-0.342717***	-0.315741***	-0.314559***
ρ_{24}	-0.047799***	-0.041530***	-0.157476***	-0.156247***	-0.188482***	-0.187489***	-0.165843***	-0.165234***
ρ_{25}	-0.014211	-0.012350	-0.052586	-0.052186	-0.110412***	-0.109826***	-0.053460*	-0.053277*
ρ_{26}					-0.029754	-0.029591	0.000208	0.000207
ρ_{27}					0.002122	0.002113		
R^2	0.422027	0.513477	0.134386	0.167373	0.724285	0.741818	0.685878	0.653366
F-statistic	124.8615	180.4738	26.54764	34.37403	335.9189	367.4159	319.5669	275.8663

Notes

Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level; * Statistically significant at 10% level

Table X2-22 EG's VECM on logarithmic Standard and Poor's Silver Index and logarithmic Silver spot price

Coefficient	IUS	SMX	IUS	SUS	IUS	SAU	IUS	SUK
β	1	-1.149317***	1	-1.006417***	1	-1.003869***	1	-1.002317***
a	-0.467056***	0.463703***	0.367134***	-0.630514***	0.293126***	-0.705737***	0.427062***	-0.571955***
ρ_{11}	0.045759***	0.039814***	0.394097***	0.391584***	0.611901***	0.609543***	0.534231***	0.532988***
ρ_{12}	0.065061***	0.056608***	0.261360***	0.259695***	0.377653***	0.376188***	0.336348***	0.335569***
ρ_{13}	0.056488***	0.049153***	0.166693***	0.165615***	0.299271***	0.298103***	0.303138***	0.302426***
ρ_{14}	0.055729***	0.048483***	0.123745**	0.122946**	0.286413***	0.285301***	0.237434***	0.236889***
ρ_{15}	0.048436***	0.042137***	0.055359	0.054984	0.149981***	0.149395***	0.139082***	0.138772***
ρ_{16}	0.009748	0.008476			0.078637***	0.078320***	0.019464	0.019424
ρ_{17}					0.007201	0.007176		
ρ_{21}	-0.054975***	-0.047829***	-0.387907***	-0.385437***	-0.423281***	-0.421638***	-0.394631***	-0.393716***
ρ_{22}	-0.076264***	-0.066351***	-0.215972***	-0.214604***	-0.346262***	-0.344918***	-0.354194***	-0.353370***
ρ_{23}	-0.054129***	-0.047097***	-0.154455**	-0.153456**	-0.299564***	-0.298399***	-0.277396***	-0.276755***
ρ_{24}	-0.049517***	-0.043080***	-0.101770*	-0.101108*	-0.159361***	-0.158741***	-0.143132***	-0.142803***
ρ_{25}	-0.017234	-0.014993	-0.049522	-0.049184	-0.083504***	-0.083171***	-0.039384	-0.039302
ρ_{26}	0.005682	0.004941			-0.009987	-0.009948	0.004313	0.004302
ρ_{27}					0.004260	0.004246		
R^2	0.418701	0.507709	0.126666	0.165250	0.723967	0.743131	0.687345	0.687345
F-statistic	105.4189	150.9409	24.80144	33.85172	335.3855	369.9464	321.7542	321.7542

Notes

Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level; * Statistically significant at 10% level

Table X2-23

Pairwise Granger Causality Tests of Silver
Sample: 3/24/2000 2/29/2008
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.	Decision
SAU does not Granger Cause FJPTOCOM	2069	62.9253***	3.E-27	False
FJPTOCOM does not Granger Cause SAU		1.05618	0.3480	True
SUK does not Granger Cause FJPTOCOM	2069	89.0778***	8.E-38	False
FJPTOCOM does not Granger Cause SUK		1.64460	0.1933	True
SUS does not Granger Cause FJPTOCOM	2069	657.142***	1E-221	False
FJPTOCOM does not Granger Cause SUS		1.46283	0.2318	True

Appendix III

Unit Root Tests Results for Price Series of Platinum

Table X3-01

Augmented Dickey-Fuller (ADF) Unit Root Tests for Various logarithmic Prices of Platinum

Panel a	Level (lnP)			
Variable	Lag Length	ADF Test Statistic	Prob.#	Critical Value at 10%
FUS^{CBOT}	0	-1.620228	0.7850	-3.127895
FUS^{COMEX}	0	-1.856491	0.6766	-3.127895
FJP	0	-1.240479	0.9010	-3.127895
IML	0	-1.210181	0.9074	-3.127895
ISP	0	-1.452317	0.8453	-3.127895
SAU	1	-1.258579	0.8971	-3.127895
SMX	4	-1.312010	0.8845	-3.127895
SUK	0	-0.952853	0.9483	-3.127896
SUS	0	-1.620228	0.7850	-3.127895
Panel b	First difference (ΔlnP)			
Variable	Lag Length	ADF Test Statistic	Prob.#	Critical Value at 1%
FUS^{CBOT}	0	-47.65892***	0.0001	-3.433312
FUS^{COMEX}	0	-43.91635***	0.0001	-3.433312
FJP	0	-45.12812***	0.0001	-3.433312
IML	0	-44.60306***	0.0001	-3.433312
ISP	0	-44.78995***	0.0001	-3.433312
SAU	0	-46.44540***	0.0001	-3.433312
SMX	3	-46.65321***	0.0001	-3.433312
SUK	0	-35.38395***	0.0000	-3.433314
SUS	0	-47.65892***	0.0001	-3.433312

Note:
All the estimated price series are from March of 2000 to February of 2008
Trend and intercept are added in test at level; and only intercept is added at difference level
Optimal lag lengths chosen by Schwarz Info Criterion (SIC)
Asymptotic critical values are from Davidson and Mackinnon (1993)
#MacKinnon (1996) one-sided p-values.
Asterisks denotes: *** Significant at 1% level; ** Significant at 5% level; * Significant at 10% level

Table X3-02

Phillip-Perron (PP) Unit Root Tests for Various logarithmic Prices of Platinum

Panel a	Level (lnP)			
Variable	BW	PP Test Statistic	Prob.#	Critical Value at 10%
FUS^{CBOT}	6	-1.410675	0.8579	-3.127895
FUS^{COMEX}	7	-2.025948	0.5862	-3.127895
FJP	0	-1.240479	0.9010	-3.127895
IML	3	-1.188052	0.9118	-3.127895
ISP	2	-1.423461	0.8541	-3.127895
SAU	6	-1.062037	0.9335	-3.127895
SMX	0	-1.312010	0.8845	-3.127895
SUK	5	-1.096153	0.9281	-3.127895
SUS	6	-1.410675	0.8579	-3.127895
Panel b	First difference (ΔlnP)			
Variable	BW	PP Test Statistic	Prob.#	Critical Value at 1%
FUS^{CBOT}	5	-47.72174***	0.0001	-3.433312
FUS^{COMEX}	5	-43.91567***	0.0001	-3.433312
FJP	2	-45.12810***	0.0001	-3.433312
IML	1	-44.60313***	0.0001	-3.433312
ISP	1	-44.79023***	0.0001	-3.433312
SAU	6	-46.51483***	0.0001	-3.433312
SMX	1	-46.65407***	0.0001	-3.433312
SUK	5	-46.63823***	0.0001	-3.433312
SUS	5	-47.72174***	0.0001	-3.433312

Note:
All the price series are from March of 2000 to February of 2008
Trend and intercept are added in test at level, apart from only intercept is contained in unit root test of CMXC; and only intercept is added at difference level
BW is the bandwidth chosen by Newey-West automatic truncation lag
#MacKinnon (1996) one-sided p-values.
Asterisks denotes: *** Significant at 1% level; ** Significant at 5% level; * Significant at 10% level

Lag Length for Estimations on Platinum

Table X3-03

Lag Length for Estimations on Platinum

Variables	SAU	SMX	SUK	SUS
FUS^{NYMEX}	5	4	5	4
FJP	4	5	5	7
IML	7	5	6	6
ISP	7	5	5	6

Cointegration Results of Pairwised Log Platinum Price Series

Table X3- 04

EG's Cointegration tests on
Logarithmic NYMEX Platinum Futures Price and Logarithmic Spot Prices of Platinum

Variables	ADF Test	PP Test	Conclusion
FUS^{COMEX} and SAU	-7.339251***	-24.08921***	Cointegrated
FUS^{COMEX} and SMX	-8.500661***	-12.04273***	Cointegrated
FUS^{COMEX} and SUK	-6.920389***	-17.23412***	Cointegrated
FUS^{COMEX} and SUS	-7.445164***	-15.64869***	Cointegrated

Notes:
*** Statistically significant at 1% level; ** Statistically significant at 5% level

Table X3- 05

EG's Cointegration tests on
Logarithmic Merrill Lynch's Platinum Index and Logarithmic Spot Prices of Platinum

Variables	ADF Test	PP Test	Conclusion
FUS^{CBOT} and SAU	-5.931996***	-41.80051***	Cointegrated
FUS^{CBOT} and SMX	-5.068256***	-19.76250***	Cointegrated
FUS^{CBOT} and SUK	-6.140123***	-35.21339***	Cointegrated
FUS^{CBOT} and SUS	-5.715834***	-30.52741***	Cointegrated

Notes: *** Statistically significant at 1% level; ** Statistically significant at 5% level

Table X3- 06

EG's Cointegration tests on
Logarithmic S&P's Platinum Index and Logarithmic Spot Prices of Platinum

Variables	ADF Test	PP Test	Conclusion
IML and SAU	-6.970563***	-40.14364***	Cointegrated
IML and SMX	-5.996718***	-20.96637***	Cointegrated
IML and SUK	-7.731361***	-35.04234***	Cointegrated
IML and SUS	-6.656940***	-31.27882***	Cointegrated

Notes:
*** Statistically significant at 1% level; ** Statistically significant at 5% level

Table X3- 07

EG's Cointegration tests on
Logarithmic TOCOM Platinum Futures Price and Various Logarithmic Spot Prices of Platinum

Variables	ADF Test	PP Test	Conclusion
IML and SAU	-6.970563***	-40.14364***	Cointegrated
IML and SMX	-2.740427***	-3.153528***	Cointegrated
IML and SUK	-2.760976***	-3.557347***	Cointegrated
IML and SUS	-2.674051***	-3.280386***	Cointegrated

Notes:
*** Statistically significant at 1% level; ** Statistically significant at 5% level

Table X3- 08

Johansen's Cointegration tests on
Logarithmic NYMEX Platinum Futures Price and Logarithmic Spot Prices of Platinum

Price Variables	H_0: rank=r	H_1: rank=r	λ_{trace} Statistics	Critical Values	H_0: rank=r	H_1: rank=r	λ_{max} Statistics	Critical Values
$FUS^{COMEX}$and SAU	r = 0	r > 0	54.94996* 3.823121	25.87211 12.51798	r = 0 r = 1	r = 1 r = 2	51.12684* 3.823121	19.38704 12.51798
	r ≤ 1	r > 1	54.94996* 3.823121	25.87211 12.51798	r = 0 r = 1	r = 1 r = 2	51.12684* 3.823121	19.38704 12.51798
$FUS^{COMEX}$and SNY	r = 0	r > 0	55.46635* 3.464043	25.87211 12.51798	r = 0 r = 1	r = 1 r = 2	52.00231* 3.464043	19.38704 12.51798
	r ≤ 1	r > 1	55.46635* 3.464043	25.87211 12.51798	r = 0 r = 1	r = 1 r = 2	52.00231* 3.464043	19.38704 12.51798
$FUS^{COMEX}$and SUK	r = 0	r > 0	57.94369* 3.615711	25.87211 12.51798	r = 0 r = 1	r = 1 r = 2	54.32798* 3.615711	19.38704 12.51798
	r ≤ 1	r > 1	57.94369* 3.615711	25.87211 12.51798	r = 0 r = 1	r = 1 r = 2	54.32798* 3.615711	19.38704 12.51798
$FUS^{COMEX}$and SUS	r = 0	r > 0	57.05584* 3.488498	25.87211 12.51798	r = 0 r = 1	r = 1 r = 2	53.56734* 3.488498	19.38704 12.51798
	r ≤ 1	r > 1	57.05584* 3.488498	25.87211 12.51798	r = 0 r = 1	r = 1 r = 2	53.56734* 3.488498	19.38704 12.51798

Notes:
* denotes rejection of the hypothesis at the 0.05 level
Critical Value is at 5% significant

Table X3- 09

Johansen's Cointegration tests on
Logarithmic Merrill Lynch's Platinum Index and Logarithmic Spot Prices of Platinum

Price Variables	H_0: rank=r	H_1: rank=r	λ_{trace} Statistics	Critical Values	H_0: rank=r	H_1: rank=r	λ_{max} Statistics	Critical Values
IML and SAU	r = 0	r > 0	46.86077* 4.934911	25.87211 12.51798	r = 0 r = 1	r = 1 r = 2	46.86077* 4.934911	19.38704 12.51798
	r ≤ 1	r > 1	46.86077* 4.934911	25.87211 12.51798	r = 0 r = 1	r = 1 r = 2	46.86077* 4.934911	19.38704 12.51798
IML and SNY	r = 0	r > 0	44.62932* 4.452063	25.87211 12.51798	r = 0 r = 1	r = 1 r = 2	40.17726* 4.452063	19.38704 12.51798
	r ≤ 1	r > 1	44.62932* 4.452063	25.87211 12.51798	r = 0 r = 1	r = 1 r = 2	40.17726* 4.452063	19.38704 12.51798
IML and SUK	r = 0	r > 0	45.63516* 3.969553	25.87211 12.51798	r = 0 r = 1	r = 1 r = 2	41.66561* 3.969553	19.38704 12.51798
	r ≤ 1	r > 1	45.63516* 3.969553	25.87211 12.51798	r = 0 r = 1	r = 1 r = 2	41.66561* 3.969553	19.38704 12.51798
IML and SUS	r = 0	r > 0	45.92705* 4.010809	25.87211 12.51798	r = 0 r = 1	r = 1 r = 2	41.91624* 4.010809	19.38704 12.51798
	r ≤ 1	r > 1	45.92705* 4.010809	25.87211 12.51798	r = 0 r = 1	r = 1 r = 2	41.91624* 4.010809	19.38704 12.51798

Notes:
* denotes rejection of the hypothesis at the 0.05 level
Critical Value is at 5% significant

Table X3- 10

Johansen's Cointegration tests on
Logarithmic S&P's Platinum Index and Logarithmic Spot Prices of Platinum

Price Variables	H_0: rank=r	H_1: rank=r	λ_{trace} Statistics	Critical Values	H_0: rank=r	H_1: rank=r	λ_{max} Statistics	Critical Values
ISP and SAU	r = 0	r > 0	48.46415*	25.87211	r = 0	r = 1	43.81916*	19.38704
			4.644984	12.51798	r = 1	r = 2	4.644984	12.51798
	r ≤ 1	r > 1	48.46415*	25.87211	r = 0	r = 1	43.81916*	19.38704
			4.644984	12.51798	r = 1	r = 2	4.644984	12.51798
ISP and SNY	r = 0	r > 0	49.39487*	25.87211	r = 0	r = 1	45.24365*	19.38704
			4.151228	12.51798	r = 1	r = 2	4.151228	12.51798
	r ≤ 1	r > 1	49.39487*	25.87211	r = 0	r = 1	45.24365*	19.38704
			4.151228	12.51798	r = 1	r = 2	4.151228	12.51798
ISP and SUK	r = 0	r > 0	55.28249*	25.87211	r = 0	r = 1	51.51821*	19.38704
			3.764286	12.51798	r = 1	r = 2	3.764286	12.51798
	r ≤ 1	r > 1	55.28249*	25.87211	r = 0	r = 1	51.51821*	19.38704
			3.764286	12.51798	r = 1	r = 2	3.764286	12.51798
ISP and SUS	r = 0	r > 0	54.56448*	25.87211	r = 0	r = 1	50.59571*	19.38704
			3.968773	12.51798	r = 1	r = 2	3.968773	12.51798
	r ≤ 1	r > 1	54.56448*	25.87211	r = 0	r = 1	50.59571*	19.38704
			3.968773	12.51798	r = 1	r = 2	3.968773	12.51798

Notes:
* denotes rejection of the hypothesis at the 0.05 level
Critical Value is at 5% significant

Table X3- 11

Johansen's Cointegration tests on
Logarithmic TOCOM Platinum Futures Price and Various Logarithmic Spot Prices of Platinum

Price Variables	H_0: rank=r	H_1: rank=r	λ_{trace} Statistics	Critical Values	H_0: rank=r	H_1: rank=r	λ_{max} Statistics	Critical Values
FJP and SAU	r = 0	r > 0	14.75052	25.87211	r = 0	r = 1	9.970342	19.38704
			4.780180	12.51798	r = 1	r = 2	4.780180	12.51798
	r ≤ 1	r > 1	14.75052	25.87211	r = 0	r = 1	9.970342	19.38704
			4.780180	12.51798	r = 1	r = 2	4.780180	12.51798
FJP and SNY	r = 0	r > 0	15.90832	25.87211	r = 0	r = 1	10.44155	19.38704
			5.466775	12.51798	r = 1	r = 2	5.466775	12.51798
	r ≤ 1	r > 1	15.90832	25.87211	r = 0	r = 1	10.44155	19.38704
			5.466775	12.51798	r = 1	r = 2	5.466775	12.51798
FJP and SUK	r = 0	r > 0	14.59647	25.87211	r = 0	r = 1	10.07888	19.38704
			4.517588	12.51798	r = 1	r = 2	4.517588	12.51798
	r ≤ 1	r > 1	14.59647	25.87211	r = 0	r = 1	10.07888	19.38704
			4.517588	12.51798	r = 1	r = 2	4.517588	12.51798
FJP and SUS	r = 0	r > 0	16.66138	25.87211	r = 0	r = 1	10.32405	19.38704
			6.337330	12.51798	r = 1	r = 2	6.337330	12.51798
	r ≤ 1	r > 1	16.66138	25.87211	r = 0	r = 1	10.32405	19.38704
			6.337330	12.51798	r = 1	r = 2	6.337330	12.51798

Notes:
* denotes rejection of the hypothesis at the 0.05 level
Critical Value is at 5% significant

Johansen's Error Correction Estimations on Platinum Price Series

Table X3-12 Johansen's VECM on logarithmic MYMEX Platinum futures price and logarithmic Platinum spot price

Coefficient	FUS	SNY	FUS	SUS	FUS	SAU	FUS	SUK
β	1	-1.025130***	1	-1.027797***	1	-1.025741***	1	-1.023173***
a	-0.062008***	0.011415	-0.059034***	0.027039**	-0.061806***	0.043375***	-0.063779***	0.028017**
ρ_{11}	-0.048311	0.255227***	-0.019491	0.345533***	-0.002297	0.538344***	-0.020089	0.379991***
ρ_{12}	-0.007284	0.085398***	-0.001811	0.181221***	0.035438	0.231017***	0.020533	0.198526***
ρ_{13}	-0.059138*	0.014213	-0.073136**	0.029955	-0.044695	0.150544***	-0.057115*	0.070537***
ρ_{14}	-0.028721	0.015311	-0.027660	0.025500	-0.022948	0.083481***	-0.005286	0.051092*
ρ_{15}					0.042622	0.026706	0.038494	0.008737
ρ_{21}	0.016756	-0.223602***	-0.021544	-0.278952***	-0.023510	-0.272162***	-0.013453	-0.306843***
ρ_{22}	0.011265	-0.068768**	0.017430	-0.198926***	-0.051843	-0.201449***	-0.017521	-0.195719***
ρ_{23}	-0.002018	-0.072952***	0.021582	-0.032026	0.046676	-0.114059***	0.007876	-0.074889**
ρ_{24}	0.035375	-0.016731	0.031955	-0.008847	-0.005679	-0.036862	0.002215	-0.045992
ρ_{25}					-0.035659	-0.014304	-0.011620	0.016162
R^2	0.016633	0.040592	0.015321	0.099956	0.019218	0.348276	0.016053	0.121344
F-statistic	3.864018	9.665322	3.554430	25.37028	3.656978	99.73716	3.044959	25.77489

Notes

Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level; * Statistically significant at 10% level

Table X3-13 Johansen's VECM on logarithmic Merrill Lynch's Platinum Index and logarithmic Platinum spot price

Coefficient	IUS	SNY	IUS	SUS	IUS	SAU	IUS	SUK
β	1	-1.033694***	1	-1.035115***	1	-1.033511***	1	-1.030125***
a	-0.084319***	-0.017930	-0.066317***	0.028305	-0.082873***	0.056056***	-0.073519***	0.033210
ρ_{11}	0.027005	0.635107***	0.071355*	0.693187***	0.093276***	0.755557***	0.062187	0.720355***
ρ_{12}	-0.035593	0.325390***	-0.010368	0.470507***	0.085447**	0.546322***	0.001265	0.506480***
ρ_{13}	-0.175390***	0.071973	-0.165208***	0.189642***	-0.072122	0.381307***	-0.137970***	0.260487***
ρ_{14}	-0.008438	0.098821*	-0.061304	0.147855***	-0.036682	0.291464***	-0.037134	0.202199***
ρ_{15}	0.027677	0.019269	-0.034185	0.050950	-0.008799	0.169942***	-0.041759	0.059236
ρ_{16}			-0.025984	0.001631	-0.020110	0.121002***	-0.044106	-0.003379
ρ_{17}					0.014740	0.058697**		
ρ_{21}	-0.019473	-0.599400***	-0.072433	-0.626372***	-0.111655***	-0.583805***	-0.054858	-0.653205***
ρ_{22}	0.038676	-0.304285***	0.036199	-0.460658***	-0.059183	-0.452201***	0.019000	-0.479595***
ρ_{23}	0.092437	-0.139947**	0.092020*	-0.204241***	0.068806	-0.314332***	0.063615	-0.271747***
ρ_{24}	0.004541	-0.093610	0.067334	-0.107979**	0.021480	-0.198168***	0.042103	-0.161563***
ρ_{25}	-0.020319	-0.017484	0.044342	-0.053299	0.000902	-0.135374***	0.063930	-0.015696
ρ_{26}			0.002963	-0.004832	0.007824	-0.076202***	0.019607	-0.001227
ρ_{27}					-0.025352	-0.010970		
R^2	0.015907	0.085822	0.016172	0.201338	0.020670	0.538381	0.014749	0.243827
F-statistic	3.016826	17.52125	2.592123	39.75319	2.880321	159.1598	2.360639	50.84772

Notes

Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level; * Statistically significant at 10% level

Table X3-14 Johansen's VECM on logarithmic Standard and Poor's Platinum Index and logarithmic Platinum spot price

Coefficient	IUS	SNY	IUS	SUS	IUS	SAU	IUS	SUK
β	1	-1.021889***	1	-1.023724***	1	-1.022054***	1	-1.019212***
a	-0.055970*	0.025954	-0.038002	0.075093***	-0.061805**	0.085252***	-0.041557	0.084078***
ρ_{11}	0.107140*	0.662588***	0.116934***	0.683191***	0.103117***	0.729123***	0.099116**	0.705435***
ρ_{12}	0.055815	0.353409***	0.036776	0.465815***	0.112762***	0.508706***	0.050366	0.494467***
ρ_{13}	-0.069029	0.107897*	-0.078972	0.217733***	-0.023625	0.360498***	-0.056776	0.270103***
ρ_{14}	0.091633	0.152333***	0.026135	0.182234***	0.026228	0.290447***	0.042755	0.219073***
ρ_{15}	0.096758*	0.055865	0.050517	0.096804**	0.069849	0.158391***	0.031249	0.080647**
ρ_{16}			0.035095	0.038865	0.034554	0.126527***		
ρ_{17}					0.028048	0.065447***		
ρ_{21}	-0.095376*	-0.627070***	-0.120021***	-0.623664***	-0.141598***	-0.558882***	-0.099789**	-0.647234***
ρ_{22}	-0.055322	-0.331290***	-0.012848	-0.461823***	-0.087184*	-0.422803***	-0.034983	-0.472930***
ρ_{23}	-0.005297	-0.170399***	0.005437	-0.234567***	0.011906	-0.311741***	-0.015629	-0.283007***
ρ_{24}	-0.090452	-0.141482**	-0.018827	-0.144674***	-0.049401	-0.192944***	-0.034559	-0.178678***
ρ_{25}	-0.072727	-0.045765	-0.028250	-0.094015**	-0.055653	-0.134570***	0.006311	-0.029430
ρ_{26}			-0.044452	-0.033825	-0.011924	-0.080650***		
ρ_{27}					-0.031884	-0.013354		
R^2	0.011029	0.094454	0.012916	0.211257	0.017081	0.548241	0.010461	0.257782
F-statistic	2.081437	19.46736	2.063342	42.23633	2.371479	165.6121	1.972980	64.82113

Notes

Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level; * Statistically significant at 10% level

EG's Error Correction Estimations on Platinum Price Series

Table X3-15 EG's VECM on logarithmic NYMEX Platinum futures price and logarithmic Platinum spot price

Coefficient	FUS	SNY	FUS	SUS	FUS	SAU	FUS	SUK
β	1	-1.020443***	1	-1.023510***	1	-1.019335***	1	-1.018460***
a	-0.621298***	0.371117***	-0.606350***	0.384608***	-0.685794***	0.308241***	-0.634029***	0.359334***
ρ_{11}	0.137739***	0.134990***	0.203832***	0.199141***	0.382055***	0.374811***	0.235312***	0.231053***
ρ_{12}	0.049259	0.048261	0.110073***	0.107527***	0.174544***	0.171236***	0.134173***	0.131742***
ρ_{13}	-0.015086	-0.014781	-0.011264	-0.011012	0.093229***	0.091458***	0.023466	0.023043
ρ_{14}	-0.002251	-0.002201	0.004310	0.004209	0.052090**	0.051106***	0.030312	0.029767
ρ_{15}					0.031500	0.030905	0.019532	0.019174
ρ_{21}	-0.130466***	-0.127858***	-0.179222***	-0.175092***	-0.200266***	-0.196467***	-0.200763***	-0.197115***
ρ_{22}	-0.037195	-0.036441	-0.114588***	-0.111947***	-0.158531***	-0.155520***	-0.131157***	-0.128780***
ρ_{23}	-0.045116	-0.044217	-0.010534	-0.010280	-0.066760***	-0.065490***	-0.044400	-0.043595
ρ_{24}	0.004196	0.004112	0.007698	0.007529	-0.027631	-0.027102	-0.028107	-0.027599
ρ_{25}					-0.020811	-0.020422	0.006422	0.006310
R^2	0.196180	0.124139	0.247399	0.208298	0.508640	0.449835	0.282515	0.221644
F-statistic	50.15427	29.12630	67.55298	54.06724	177.0137	139.8158	67.33241	48.69380

Notes

Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level; * Statistically significant at 10% level

Table X3-16 EG's VECM on logarithmic TOCOM Platinum futures price and logarithmic Platinum spot price

Coefficient	FJP	SNY	FJP	SUS	FJP	SAU	FJP	SUK
β	1	-0.956564***	1	-0.959466***	1	-0.956062***	1	
a	-0.407802***	0.619084***	-0.406368***	0.618703***	-0.546727***	0.474099***	-0.430403***	-0.954971***
ρ_{11}	-0.154716***	-0.161732***	-0.134476***	-0.140144***	0.116232***	0.121574***	-0.129148***	0.596466***
ρ_{12}	-0.053305**	-0.055719**	-0.044724*	-0.046609*	0.057354**	0.059974**	-0.021369	-0.135248***
ρ_{13}	0.002908	0.003046	0.013237	0.013795	0.043295	0.045280	0.009569	-0.022381
ρ_{14}	0.039040*	0.040818*	0.026990	0.028125	0.059181**	0.061903**	0.033460	0.010032
ρ_{15}	-0.018463	-0.019294	-0.046899*	-0.048893*				0.035040
ρ_{16}			0.013340	0.013894				-0.038749
ρ_{17}			-0.033185	-0.034600				
ρ_{21}	0.266408***	0.278503***	0.241118***	0.251301***	-0.007181	-0.007505	0.217246***	0.227505***
ρ_{22}	0.142614***	0.149086***	0.068398***	0.071286***	-0.092200***	-0.096424***	0.057596**	0.060323
ρ_{23}	-0.002946	-0.003079	0.026524	0.027639	-0.083443***	-0.087278***	0.004018	0.004201
ρ_{24}	0.000925	0.000957	-0.019193	-0.019998	-0.024742	-0.025882	-0.035876	-0.037563
ρ_{25}	-0.023115	-0.024169	-0.004228	-0.004403			0.016094	0.016846
ρ_{26}			0.035122	0.036613				
ρ_{27}			0.027808	0.028987				
R^2	0.353734	0.347516	0.288919	0.309256	0.229959	0.203952	0.267150	0.265481
F-statistic	93.59709	91.07554	51.95680	57.25151	61.36891	0.011709	62.33558	61.80551

Notes

Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level; * Statistically significant at 10% level

Table X3-17 EG's VECM on logarithmic Merrill Lynch's Platinum Index and logarithmic Platinum spot price

Coefficient	IUS	SNY	IUS	SUS	IUS	SAU	IUS	SUK
β	1	-1.028765***	1	-1.031819***	1	-1.027564***	1	-1.026687***
a	-0.537357***	0.449724***	-0.616537***	0.371632***	-0.764457***	0.229226***	-0.688772***	0.303122***
ρ_{11}	0.330652***	0.321397***	0.462723***	0.448463***	0.634531***	0.617520***	0.528965***	0.515228***
ρ_{12}	0.143463**	0.139439**	0.290870***	0.281904***	0.462131***	0.449727***	0.358534***	0.349222***
ρ_{13}	-0.054947	-0.053406	0.053877	0.052219	0.295378***	0.287447***	0.141189***	0.137515***
ρ_{14}	0.044362	0.043128	0.068236	0.066126	0.229391***	0.223257***	0.131100***	0.127692***
ρ_{15}	0.023305	0.022647	0.017982	0.017435	0.135972***	0.132335***	0.028373	0.027628
ρ_{16}			-0.009568	-0.009278	0.093946***	0.091434***	-0.016482	-0.016056
ρ_{17}					0.050472**	0.049114**		
ρ_{21}	-0.308154***	-0.299528***	-0.420835***	-0.407868***	-0.498095***	-0.484734***	-0.478887***	-0.466448***
ρ_{22}	-0.130574**	-0.126918*	-0.274459***	-0.266000***	-0.380081***	-0.369878***	-0.333100***	-0.324453***
ρ_{23}	-0.020970	-0.020386	-0.091358*	-0.088552*	-0.241529***	-0.235054***	-0.171964***	-0.167498***
ρ_{24}	-0.043053	-0.041856	-0.040550	-0.039303	-0.156441***	-0.152261***	-0.100593**	-0.097972**
ρ_{25}	-0.017997	-0.017482	-0.015388	-0.014924	-0.109582***	-0.106666***	0.009447	0.009207
ρ_{26}			-0.001309	-0.001258	-0.060156**	-0.058546**	0.005676	0.005537
ρ_{27}					-0.014010	-0.013632		
R^2	0.066289	0.136966	0.162806	0.254207	0.549644	0.571414	0.223765	0.281961
F-statistic	12.14021	27.13811	28.46149	49.88652	156.0673	170.4900	42.19038	57.47181

Notes

Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level; * Statistically significant at 10% level

Table X3-18 EG's VECM on logarithmic Standard and Poor's Platinum Index and logarithmic Platinum spot price

Coefficient	IUS	SNY	IUS	SUS	IUS	SAU	IUS	SUK
β	1	-1.021209***	1	-1.024227***	1	-1.019963***	1	-1.019117***
a	-0.538387***	0.452040***	-0.599523***	0.391006***	-0.739778***	0.255136***	-0.661834***	0.331823***
ρ_{11}	0.406440***	0.397995***	0.486809***	0.475273***	0.612974***	0.600981***	0.539602***	0.529477***
ρ_{12}	0.215981***	0.211493***	0.316257***	0.308765***	0.435716***	0.427186***	0.372691***	0.365702***
ρ_{13}	0.024946	0.024425	0.112754**	0.110076**	0.287731***	0.282090***	0.179191***	0.175835***
ρ_{14}	0.124988**	0.122392**	0.128128***	0.125090***	0.240943***	0.236208***	0.171015***	0.167822***
ρ_{15}	0.075652	0.074088	0.081531*	0.079601*	0.142395***	0.139603***	0.067432*	0.066174*
ρ_{16}			0.038208	0.037288	0.109482***	0.107339***		
ρ_{17}					0.058654**	0.057502**		
ρ_{21}	-0.381735***	-0.373802***	-0.449266***	-0.438617***	-0.482470***	-0.473024***	-0.497645***	-0.488308***
ρ_{22}	-0.203818***	-0.199579	-0.304872***	-0.297652***	-0.360909***	-0.353838***	-0.352652***	-0.346039***
ρ_{23}	-0.093707	-0.091755	-0.150577***	-0.147007***	-0.250677***	-0.245751***	-0.209488***	-0.205563***
ρ_{24}	-0.118564**	-0.116095**	-0.101039**	-0.098645**	-0.166509***	-0.163240***	-0.139399***	-0.136792***
ρ_{25}	-0.058822	-0.057609	-0.071527*	-0.069839*	-0.120407***	-0.118043***	-0.019484	-0.019121
ρ_{26}			-0.038314	-0.037395	-0.067874***	-0.066536***		
ρ_{27}					-0.017357	-0.017013		
R^2	0.066429	0.135918	0.167312	0.257199	0.560837	0.581468	0.229028	0.291052
F-statistic	12.16774	26.89790	29.40745	50.67706	163.3037	177.6572	50.79805	70.20261

Notes

Asterisks denotes: *** Statistically significant at 1% level; ** Statistically significant at 5% level; * Statistically significant at 10% level

Table X3-19
Pairwise Granger Causality Tests of Platinum
Sample: 3/24/2000 2/29/2008
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.	Decision
SAU does not Granger Cause FJPTOCOM	2069	29.3592***	3.E-13	False
FJPTOCOM does not Granger Cause SAU		37.6738***	9.E-17	False
SNY does not Granger Cause FJPTOCOM	2069	199.654***	5.E-80	False
FJPTOCOM does not Granger Cause SNY		0.23585	0.7899	True
SUK does not Granger Cause FJPTOCOM	2069	129.840***	8.E-54	False
FJPTOCOM does not Granger Cause SUK		0.25945	0.7715	True
SUS does not Granger Cause FJPTOCOM	2069	151.590***	4.E-62	False
FJPTOCOM does not Granger Cause SUS		0.15938	0.8527	True