Resources Policy 35 (2010) 178–189

Contents lists available at ScienceDirect

Resources Policy

journal homepage: www.elsevier.com/locate/resourpol

An overview of global gold market and gold price forecasting

Shahriar Shafiee [a,*], Erkan Topal [b]

[a] School of Mining Engineering, Frank White Building (#43), Cooper Road, CRC Mining, University of Queensland, St. Lucia, QLD 4072, Australia
[b] Mining Engineering Department, Western Australian School of Mines, Curtin University of Technology, Kalgoorlie, WA 6433 Australia

ARTICLE INFO

Article history:
Received 6 February 2009
Received in revised form
20 April 2010
Accepted 17 May 2010

Jel classification:
E31
O13
Q32

Keywords:
Historical gold market
Forecasting mineral prices
Long-term trend reverting
Jump and dip diffusion

ABSTRACT

The global gold market has recently attracted a lot of attention and the price of gold is relatively higher than its historical trend. For mining companies to mitigate risk and uncertainty in gold price fluctuations, make hedging, future investment and evaluation decisions, depend on forecasting future price trends. The first section of this paper reviews the world gold market and the historical trend of gold prices from January 1968 to December 2008. This is followed by an investigation into the relationship between gold price and other key influencing variables, such as oil price and global inflation over the last 40 years. The second section applies a modified econometric version of the long-term trend reverting jump and dip diffusion model for forecasting natural-resource commodity prices. This method addresses the deficiencies of previous models, such as jumps and dips as parameters and unit root test for long-term trends. The model proposes that historical data of mineral commodities have three terms to demonstrate fluctuation of prices: a long-term trend reversion component, a diffusion component and a jump or dip component. The model calculates each term individually to estimate future prices of mineral commodities. The study validates the model and estimates the gold price for the next 10 years, based on monthly historical data of nominal gold price.

Introduction

In 2008 and early 2009 most metal prices fell and the global economy was in recession. Many mining companies had difficulties surviving during this period. Some reduced their production rates and postponed projects while others switched to hedge instruments or long-term contracts to guarantee commodity prices. Cash flows in mining projects are volatile and are significantly influenced by the fluctuation of mineral commodity prices. Estimation of mineral prices is vital at the beginning of the valuation process as well as in computing total costs and production rates over the entire mine life, and mining companies make decisions to accept or reject a project based on future price expectations. Consequently, it is essential to estimate future prices with suitable models during any appraisal of mining projects.

The price and production behaviour of gold differs from most other mineral commodities. In the 2008 financial crisis, the gold price increased by 6% while many key mineral prices fell and other equities dropped by around 40%. The unique and diverse drivers of gold demand and supply do not correlate highly with changes in other financial assets (WGC, 2009). This study analyses the gold market and gold price trends over the past 40 years. In addition, it focuses on variables which affected gold price in that era. It then proposes and applies a new version of the mean reverting jump diffusion model. Finally, gold prices over the next 10 years are predicted using this new model.

Recent demand and supply for gold

Tables 1 and 2 illustrate the aggregate supply and demand for gold from 2002 to 2007. As can be seen in Table 1, the total supply of world gold is around 3500 tonnes per annum. The largest source of gold supply, at approximately 2500 tonnes, came from mine production. The second largest source of gold, at approximately 1000 tonnes, came from central bank sales and other disposals. Table 2 shows the demand trends for gold. On average 2500 tonnes are ascribed to jewellery and 1000 tonnes are ascribed to retail investors, Exchange Traded Funds (ETFs) and industrial production in the last 10 years (WGC, 2008). The world gold demand from 1998 to 2007 decreased, while net retail investment, ETFs and industrial demand increased. One of the peculiarities of gold demand from jewellery is that it can be converted to the supply side. This means gold is a renewable resource and, with no degradation in quality, could conceivably be recycled and contribute to a decrease in the global demand for newly mined gold. In other words, gold reserves in central banks and jewellery can enter into the supply side equation in the gold market (Batchelor and Gulley, 1995).

* Corresponding author.
E-mail addresses: s.shafiee@uq.edu.au (S. Shafiee), e.topal@curtin.edu.au (E. Topal).

0301-4207/$ - see front matter
doi:10.1016/j.resourpol.2010.05.004

Table 1
Estimated world gold supply from 2002 to 2007 (tonnes).
Source of data WGC (2008).

Year	Mine production	Net producer hedging	Total mine supply	Official sector sales	Old gold scrap	Total supply
2002	2591	−412	2179	545	835	3559
2003	2593	−279	2314	617	944	3875
2004	2463	−427	2036	471	834	3341
2005	2548	−92	2456	663	898	4017
2006	2485	−410	2075	370	1129	3574
2007	2475	−447	2028	501	967	3496

Table 2
Estimated world gold demand from 1998 to 2007 (tonnes).
Source of data WGC (2008).

Year	Jewellery	Net retail investment	ETFs and similar	Industrial and dental	Total
1998	3164	263	–	393	3820
1999	3132	359	–	412	3903
2000	3196	166	–	451	3813
2001	3001	357	–	363	3721
2002	2653	340	3	357	3353
2003	2477	293	39	381	3190
2004	2613	340	133	414	3500
2005	2708	385	208	432	3733
2006	2284	401	260	459	3404
2007	2400	403	253	461	3517

Table 3
World mine production, reserve base and depletion time in 2007 (tonnes).
Source of data USGS (2008).

No	Countries	Mine production	Reserve base	Depletion time
1	Australia	280	6000	21
2	South Africa	270	36,000	133
3	China	250	4100	16
4	United States	240	3700	15
5	Peru	170	4100	24
6	Russia	160	3500	22
7	Indonesia	120	2800	23
8	Canada	100	3500	35
9	Other countries	920	26,000	28
World (rounded)		2500	90,000	36

Table 4
World official gold reserves in selected countries from 1950 to 2008 (tonnes).
Source of data WGC (2008).

No.	Countries/ organization	1950	1960	1970	1980	1990	2000	2008
1	United States	20,279	15,822	9839	8221	8146	8137	8133
2	Germany	0	2640	3537	2960	2960	3701	3417
3	France	588	1458	3139	2546	2546	3184	2562
4	Italy	227	1958	2565	2074	2074	2593	2451
5	Switzerland	1306	1942	2427	2590	2,590	2,590	1,100
6	China	–	–	–	398	395	395	600
7	South Africa	175	158	592	378	127	124	124
8	Australia	79	131	212	247	247	80	80
9	World total (rounded)	31,100	35,900	36,600	35,800	35,600	33,500	30,000

Table 3 details the global supply of gold and the major producing countries in 2007. Australia, South Africa, China and the United States produced more than 40% of gold globally in 2007. Moreover, the depletion time or proportion of mine production to reserves shows that, on average, world gold reserves will diminish in less than 40 years. Some scientists believe that new reserves and production data will postpone depletion times (Seifritz, 2003; Klass, 1998). Price fluctuation is another factor that can affect available reserves (Shafiee and Topal, 2008a, 2009).

Gold reserves in central banks are one of the largest sources of world gold supply. Table 4 shows countries which hold gold reserves in the central bank for more than half a century. As can be seen, the United States holds the greatest amount of gold reserves in their central bank in comparison to other countries. It should be noted, however, that the US reduced its gold bank reserves by more than 60% during the US crisis in the 1970s. Germany, France and Italy are the other major countries which individually keep gold bank reserves similar to the level of that held by the International Monetary Fund (IMF), around 3000 tonnes. Consequently, the level of gold bank reserves in the last 50 years has remained constant at approximately 30,000 tonnes per year, although distributions of gold reserves in central banks between countries have changed.

The World Gold Council (WGC, 2009) estimates that the total gold mined in history to 2008 is approximately 160,000 tonnes. As can be seen in Table 4, of around the 30,000 tonnes of gold held in the central bank reserves, 30,000 tonnes are used in industrial and dental production and approximately 100,000 tonnes are kept as jewellery (Table 2). In other words, roughly 15 g of gold per head of population is distributed between people around the world. The total value of the gold kept in jewellery, central bank reserves and industrial usage is $2.9, $0.9 and $0.9 trillion, respectively, at the 2008 average gold price of $896 per ounce (US $).

Historical gold price trends

Previous studies show that gold price fluctuations have different effects on gold production and the value of gold mining stocks from country to country and mine to mine (Blose, 1996; Blose and Shieh, 1995; Craig and Rimstidt, 1998; Doggett and Zhang, 2007; Govett and Govett, 1982; Rockerbie, 1999; Selvanathan and Selvanathan, 1999). As can be seen in Fig. 1, from

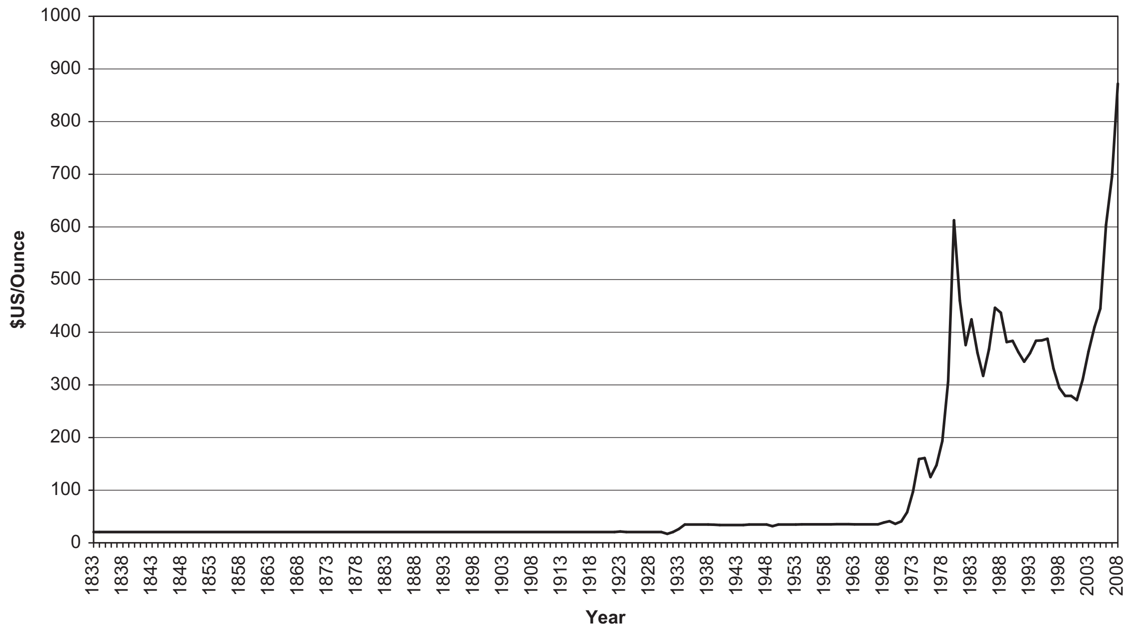

Fig. 1. The monthly historical trend of the nominal gold prices from 1833 to 2008.
Source of data: KITCO (2009).

1833 to 1933 gold prices were constant at around $20 per ounce and from 1934 to 1967 increased to $35 per ounce after President Roosevelt fixed the gold price in 1934 and remaining stable until 1967 when the gold price was freed. Gold was traded in the market from 1967 and the price increased with rapid fluctuations from then on (Mills, 2004). Therefore, this study focuses on the historical trend of the gold price from 1968 to 2008.

Fig. 1 depicts two significant gold price jumps in the historical trend. The first was in early January 1980, when gold prices reached $300 in just three weeks, and plunged significantly in mid-March that same year. The gold price on the 16th and the 18th of January increased by $75 and $85, respectively, jumping a total of $160 in less than three days. The second historical jump in price is currently in progress. Starting in 2008, this increase is substantially more firmly based and less volatile than the first price jump in 1980. In the current jump, the gold price has increased by nearly $700 over 6 years, and is continuously increasing. The highest price of gold in the second jump was around $1011 on the 17th March 2008, with the largest daily jump in gold price around $70 on the 18th of September 2008. There are several factors contributing to short-term and long-term gold price escalations.

In the short-term there are two main reasons why gold prices dramatically increase. Firstly, in a period where global financial markets crash and the global economy is in recession, investors are less trusting of financial markets as reliable investments. Consequently, they switch to speculation or to any market that does not have heavy liability or unpredictability, such as the gold market. In other words, the gold market operates as a type of insurance against extreme movements in the value of traditional assets during unstable financial markets. Secondly, the devaluation of the US dollar versus other currencies, and international inflation with high oil prices are reasons why big companies to hedge gold against fluctuations in the US dollar and inflation. This means that gold trading will offset the potential movement of real value in the short-term market against US dollar oscillations and inflation.

In the long-term, there are three major reasons for increasing gold prices. Firstly, mine production has gradually reduced in recent years (Fig. 2). Increased mining costs, decreased exploration and difficulties in finding new deposits are some of the factors which may have contributed to this reduction in mine production. Secondly, institutional and retail investment has rational expectations when markets are uncertain. They therefore keep gold in their investment portfolios as it is more liquid or marketable in unstable financial markets. Thirdly, investing in gold is becoming easier via gold Exchange Traded Funds (ETFs) compared to other finance markets, as can be seen in Table 2. Gold ETFs have stimulated the demand side of gold because it has become as easy to trade as it is to trade any stock or share (WGC, 2008).

The relation between gold price, crude oil price and inflation

The oil price and inflation rate are two main macroeconomic variables that influence the gold market (Tully and Lucey, 2007). There is a positive correlation between gold and crude oil prices. Crude oil and gold continue to break the trend of historical prices recorded in 2008. Fig. 3 illustrates the monthly trend of gold and oil prices from January 1968 to December 2008. When oil prices reached over US $145 per barrel in July 2008 this trend then started to revert. The president of OPEC said that oil prices at US $200 per barrel are possible, if the US dollar continues to devalue with respect to other currencies. On the other hand, the gold price has followed a similar trend and reached a maximum price of around US $1011 per ounce in March 2008. Fig. 3 shows that there have been two jumps in oil prices. The first one was between 1979 and 1980. The main reason for this can be attributed to the Iranian revolution and the war between Iran and Iraq. The second jump started in the middle of 2007 and has continued until recently. The main reasons for this jump were that wars in Iraq and Afghanistan made these two countries unstable, and that sanctions were imposed on Iran for continuing uranium enrichment. These two oil shocks were followed by gold price jumps as well. The nominal oil price and nominal gold price from January 1968 until the end of December 2008 increased by 23 and 16 times, respectively. The correlation between gold and oil prices

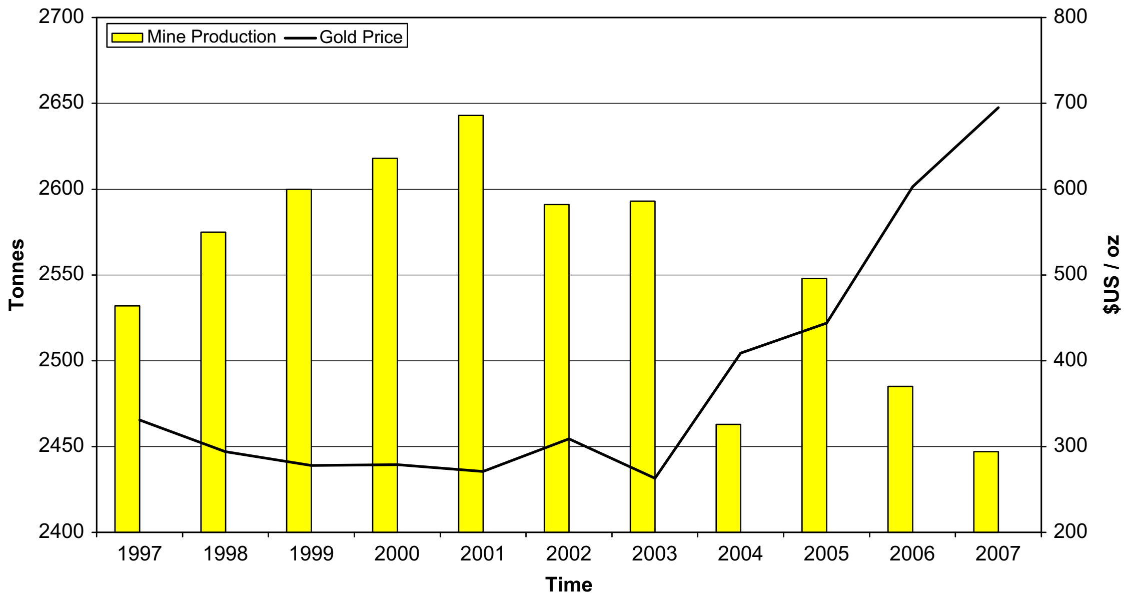

Fig. 2. The yearly gold mine production and nominal price from 1997 to 2007.
Source of data: WGC (2008).

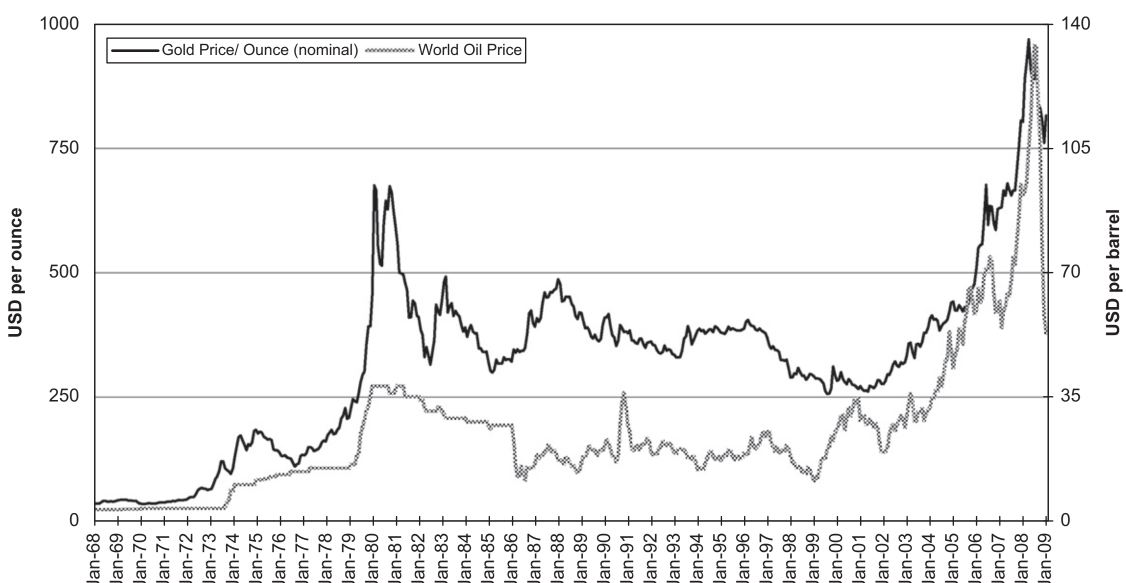

Fig. 3. The monthly historical trend of nominal oil price and nominal gold price from January 1968 to December 2008.
Source of data: IEA (2008) and KITCO (2009).

in the last four decades is calculated to be very high at approximately 85%.

As can be seen in Fig. 3 gold prices were relatively flat from 1980 to 2007. This long-term period of flat prices coincided with a period of very active forward selling in the gold industry, which took the lustre off gold price speculation. Some economists are of the belief that gold and oil prices will decrease in the long-term, while it is impossible to know when the current jump will be over.

Fig. 4 combines two mineral commodities, to measure the value of one ounce of gold to one barrel of crude oil over the last 40 years. Fig. 4 depicts the ratio of the gold price with the oil price. This ratio is independent of the value of the US currency. In other words, the graph shows how many barrels of crude oil were equivalent to one ounce of gold. For instance, in July 1973 this figure shows the maximum ratio when one ounce of gold was equivalent to 33 barrels of oil. The minimum amount was reached in June 2008 when 6.6 barrels of oil was equivalent to one ounce of gold. The volatility of this ratio in comparison to Fig. 3 is significantly lower. The ratio of gold prices to oil prices was around 11 barrels on average in 1968 and a similar figure in 2008 (Fig. 4). While the graph shows some fluctuations over the last couple of decades, the trend was fairly stable. Thus, this diagram again confirms the strong relationship between the oil and gold prices over the long-term.

Another variable that influences gold prices is inflation (Fortune, 1987; Mahdavi and Zhou, 1997). The graph in Fig. 5 shows the monthly cumulative nominal gold price growth in comparison to the cumulative US inflation from January 1968 to December 2008, as measured by monetary activities of the Federal Government and the US Treasury. The US inflation is assumed as proxy of world inflation. This figure shows that the increase in the nominal gold price was significantly less than inflation. The correlation between these two

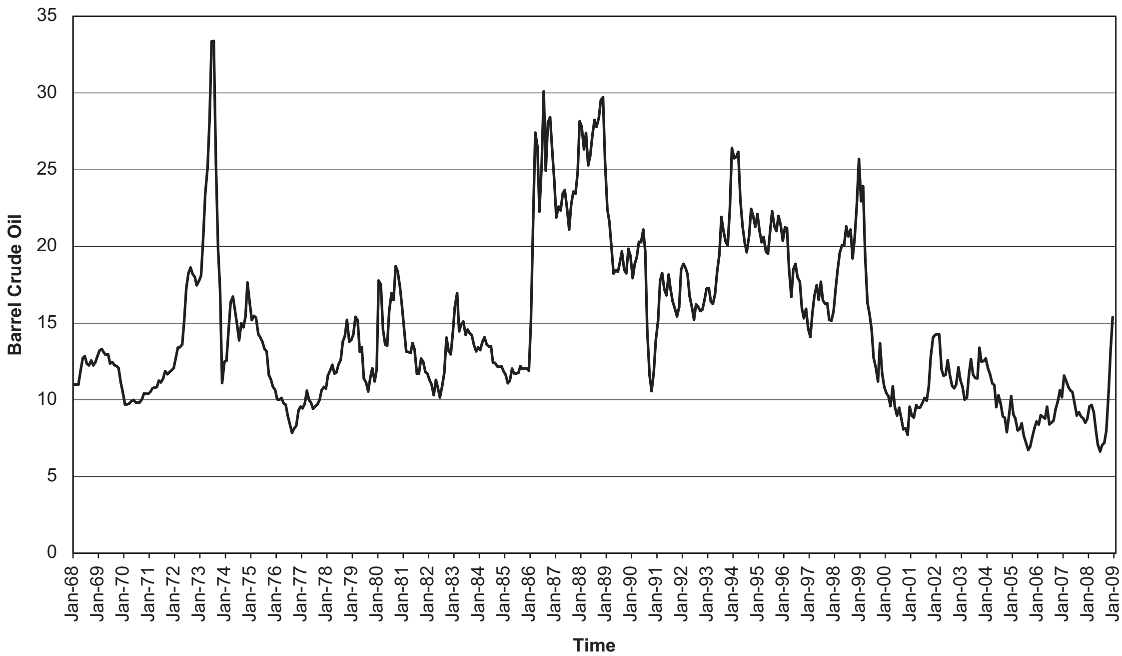

Fig. 4. The monthly historical trend of ratio between the nominal price of one ounce gold to the nominal price oil from January 1968 to December 2008. *Source of data*: IEA (2008) and KITCO (2009).

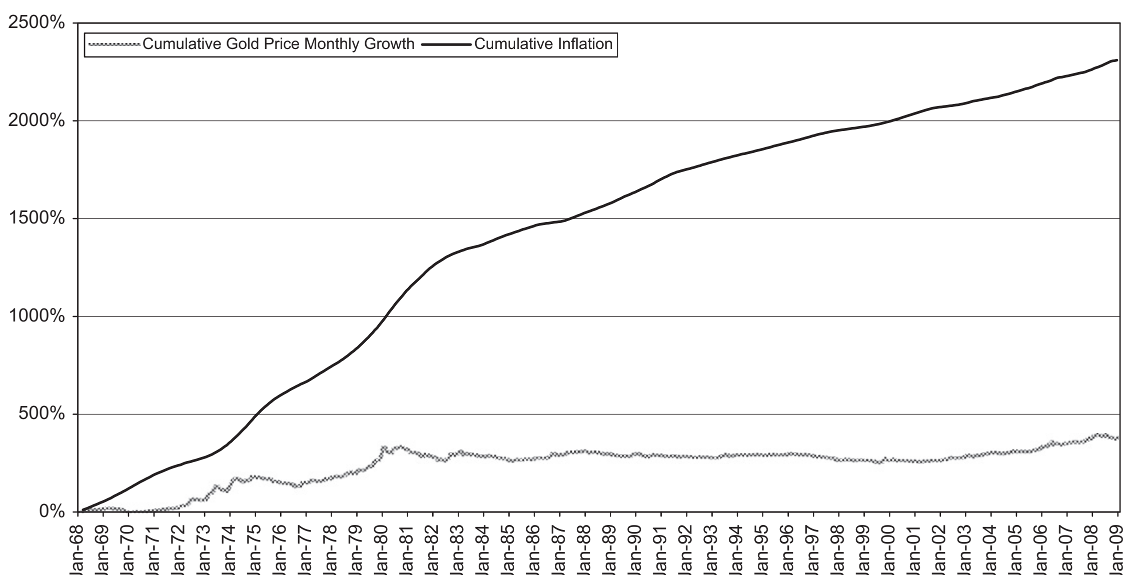

Fig. 5. The historical monthly trend of the cumulative nominal gold price growth and cumulative US inflation from January 1968 to December 2008. *Source of data*: Inflation Data (2009) and KITCO (2009).

variables is around −9% indicating that there is not any positive significant relationship between nominal gold price movements and inflation. In other words, if the nominal gold price was increased by the inflation rate over the last 40 years, the current gold price should be five times more than the current nominal price in 2008.

Long-term trend reverting jump and dip diffusion model

Literature review

There are a number of different price modelling methods that have been discussed in financial literature. The geometric Brownian motion and mean reversion are two classical approaches which form the basis for some newer methods, such as stochastic price forecasting and mean reverting jump diffusion models. These models focus on historical price movements and a random term to estimate future prices. They do not consider price jumps or dips in the models (Blanco et al., 2001; Blanco and Soronow, 2001a, b). The mean reverting jump diffusion model seeks to introduce a number of jumps per period in the model (Black and Scholes, 1973; Fama, 1965; Merton, 1973; Press, 1967). This model does not separate mean reverting rate with jump time to forecast the price. This type of model contains slightly modified assumptions from the classical models. For example, the mean reversion model modified random walk theory in geometric Brownian motion and assumes price changes are not completely independent of one another. The major problem with all of these models is that they were introduced specifically for the stock market, and thus initially applied primarily to forecast share prices or interest rate. Despite the bewildering number of models, it is crucial to know which one best fits the data used to predict the future price with minimum error. Moreover, none of the models used unit root test for time series data and econometrics methods to estimate their parameters (Shafiee and Topal, 2007). The proposed new version of mean reverting jump diffusion solves the previously mentioned models' pitfalls.

Since 1982 when Slade claimed a U-shaped time path for natural commodity prices, there has been controversy about the historical trend of natural resource prices (Ahrens and Sharma, 1997; Berck and Roberts, 1996; Mueller and Gorin, 1985; Slade, 1982, 1985, 1988, 1998). In 2006, Lee and his colleagues tested temporal properties of some non-renewable natural resource real price series. The study found that natural resource prices are stationary around deterministic trends with structural breaks in the intercepts and trend slopes (Lee et al., 2006; Shafiee and Topal, 2008b). According to microeconomics theory, in the long-term, the price of a commodity should be tied to its long-term marginal production cost (Dias and Rocha, 2001; Laughton and Jacoby, 1993). In other words, commodity prices have random short-term fluctuations, but they tend to revert to a long-term trend. For example, Bessembinder and his colleagues used econometric tests for the future trend of some commodities. For oil and agriculture prices strong mean reversion and for precious metals and financial assets a weak reversion were obtained (Bessembinder et al., 1995).

The contribution of the proposed model is to add jump and dip variables into the statistical probability distribution of actual data in previous. This will solve their discrepancies. This model adds two dummy variables in the long-trend reverting model as jump and dip. These two variables distinguish long-term trend between normal period with jump and dip period. In analysing the historical trend of gold prices in the previous section, gold prices have different jump and dip sizes, which should be considered when predicting. The jump and dip forecasting is based on an extrapolation of the historical sinusoidal trend and not statistical probabilities jump and dip (Shafiee and Topal, 2010).

Model discussion

This model uses rational expectations theory to forecast mineral commodity prices in the future. The theory defines expectations as being identical to the best guess of the future from all available information. This theory assumes that outcomes being forecasted do not differ systematically or predictably from the equilibrium results. For example, mining project evaluators assume to predict the gold price by looking at gold prices in previous years. If the economy suffers from constantly rising inflation rates or oil price pressure, the assumptions used to make a prediction are different from that time when the economy follows a smooth growth.

The model uses a stationary econometrics model to forecast gold prices. The stationary stochastic process denotes that the mean and variance of a variable are constant over the time. Moreover, covariance in the two different periods depends on gap or lag between the periods, not actual time at which the covariance is computed. For example, if the gold price time series is stationary, the mean, variance and autocovariance in various lags remain the same irrespective at what point they are measured. Therefore, some of the time series will tend to be its mean or median and fluctuate around it with constant amplitude called mean reversion.

As Kerry Patterson notes, random walk theory remembers the shock forever and it has infinite memory (Patterson, 2000). Most of the time series such as stock prices, oil prices and exchange rates follow the random walk phenomenon. This means they are nonstationary. The best prediction for tomorrow's stock price is equal to today's price plus a random shock. This means the predictions of nonstationary series do not follow any rational relationship with historical data and all movements depend on a random number. This model proposes an econometrics model that finds a long-term relationship with historical data for estimating nonstationary series. Additionally, in the new model, the size of the random shock is measured, while applied random walk theory is ignored. One of the main problems of random walk theory is that the impact of a particular shock does not die away in the long-term. For example, the average gold prices in March 2007 and 2008 were around \$654 and \$968 per ounce, respectively. If we are using these two numbers to predict gold prices for March 2009 the results will be different. The size of the jump in March 2008 influences the prediction of gold prices in March 2009.The following paragraphs details the comprehensive model for testing random walk theory and the long-term trend of the reverting jump and dip diffusion model.

The random walk theory is an example of what is known in economics literature as a unit root process. Eq. (1) demonstrates the comprehensive model of time series of X_t for testing random walk

$$X_t = \alpha_1 + \alpha_2 t + \alpha_3 X_{t-1} + u_t \tag{1}$$

where X_t is the spot price at time t, t the time measured chronologically and u_t the white noise error term.

One of the possibilities of Eq. (1) is deterministic[1] trend; it means $\alpha_1 \neq 0$, $\alpha_2 \neq 0$ and $\alpha_3 = 0$. Then Eq. (1) is converted to Eq. (2):

$$X_t = \alpha_1 + \alpha_2 t + u_t \tag{2}$$

This equation in econometrics is called a trend stationary process (TSP). The mean of X_t is $\alpha_1 + \alpha_2 t$, which is not constant, while its variance is constant. Once the value of α_1 and α_2 are regressed, the mean can be estimated perfectly. Therefore, subtracting the mean in the model will result in the series being stationary (Gujarati, 2003). The TSP model has similarities with the drift component in the mean reverting jump diffusion model. In other words, the first component or drift component in the TSP model is similar to the long-term trend of time series. The unique characteristic of this model is that it incorporates reverting long-term historical data to the long-term trend. The second component is a random component between a range of the first component. To compute this term, historical volatility or coefficient variance should be computed (γ in Eq. (3)) based on historical gold prices and then multiplied by the first component. The coefficient variance of gold prices is computed at about 25%, the second component of the model would be around $\pm 25\%$ of the first component. This term demonstrates a top and bottom to the second component gold price fluctuation. The range of this component helps the model to determine the third component. Moreover, the third component in the model adds two dummy variables in Eq. (2) to distinguish between jumps and dips time with normal trend. Some models use a statistic term for jump size in the model to estimate the future. For example, jump size for coal price was expected to be around 200% and a standard deviation of 50% for all periods (Blanco and Soronow, 2001a). If the economy suffers from constantly rising inflation rates or oil price pressure, the assumptions used to make a prediction would be different from the time that the economy follows smooth

[1] If the trend in a gold price time series is completely predictable and not variable, it is called a deterministic, whereas if it is not predictable, it is called a stochastic trend.

growth. Consequently, this model estimates dynamic jump and dip in the model as individual parameters. Eq. (3) is

$$X_t = \alpha_1 + \underbrace{\alpha_2 t}_{\substack{\text{First}\\ \text{component}\\ \text{or drift}}} + \underbrace{\alpha_2(1 \pm \gamma)}_{\substack{\text{Second}\\ \text{component}\\ \text{or the range of}\\ \text{random movements}}} + \underbrace{\alpha_3 D_1 + \alpha_4 D_2}_{\substack{\text{Third}\\ \text{component}\\ \text{or jump/dip}}} + u_t \tag{3}$$

where: D_1: $D_1=1$ if gold prices have jump and $D_1=0$ if the gold prices do not have any jump, D_2: $D_2=1$ if gold prices have dip and $D_2=0$ if the gold prices do not have any dip and γ: the historical volatility of gold prices.

This study has applied the three components of the new model to gold prices from 1968 to 2008. Following the gold price has been estimated for the next 10 years. The essential question for this model is when the gold prices are in jump or in dip. To evaluate this, the model reviews the historical price trend of jump and dip and then estimates the same trend for the future. Before applying the model, the unit root test for nominal gold price has been experimented.

The unit root test for long-term gold price

A few empirical researches based on time series data assume that the underlying time series are stationary. In other words, some of the researches ignored autocorrelation in the time series models and thus obtain a very high adjusted R^2 figure even though there is no meaningful relationship between their variables in the model (Aggarwal and Lucey, 2007; Kaufmann and Winters, 1989; Laulajainen, 1990). Some studies on mineral commodity prices showed that all price series were stationary on unit root tests (Bordo et al., 2007; Mahdavi and Zhou, 1997; Parisi et al., 2008; Varela, 1999). One of the main circumstances of the time series in comparison to cross sectional data or other data is realization (Gujarati, 2003). This means that time series data depict inferences about the underlying stochastic process. This paper, before predicting gold price, reviews this main question, whether the gold price is really following random walk or not? Basically, it is going to study gold price behaviour in long and short-term to investigate stationary.

In econometrics literature, the unit root test, also known as the Augmented Dickey Fuller (ADF) test, is commonly used for testing stationary behaviour. This test is conducted in three different random walk test forms. In other words, “the terms nonstationary, random walk, and unit root can be treated as synonymous” (Gujarati, 2003). Table 5 depicts ADF results for gold price and first differential in gold price from the previous period. As can be seen, the gold price is nonstationary and the first differential in the gold price from the previous period is stationary. Consequently, any previous price modellings that applied a nonstationary gold price series in its prediction may not deliver a reliable solution.

Most econometrics models use time series data associated with nonstationary series. To avoid the unit root problem in regression models, there are two methods available. The first one, difference stationary processes (DSF) uses the first difference of a time series. The second one uses the trend stationary processes (TSP) that simply regresses time series on time. The residuals from this type of regression will be stationary. Eq. (3) in this paper uses the TSP method to avoid the unit root problem.

Jump and dip in historical gold price

Fig. 6 depicts the regressed line of Eq. (2) or the TSP model for gold price from January 1968 to December 2008. The linear line is drift or the first component of the model for the long-term, and the long-term gold price is reverting around this line. Moreover, the volatility for gold price has been calculated to be around 25%, which means the random term or second component around the long-term trend is approximately $\pm 25\%$. The second term, similar to random walk theory, predicts spot prices in the short term. The advantage of this model is predicting the long-term gold price and anticipating the direction of spot prices in the future. Any gold price out of the 25% range of the long-term trend is called the third component or jump/dip in this model. Figs. 7 and 8 demonstrate the size of the jumps and dips in the model.

To highlight the jump and dip, Fig. 7 and Table 6 illustrate the percentage of jump and dip for the historical trend of gold prices from 1968 to 2008. For example, from August 1969 to February 1973, the real data is less than the range of the component term called dip, and from October 1968 to November 1984, the real data is higher than the range of the second component called jump. Consequently, the historical gold price has two long-term dips and jumps.

In Fig. 7, the periods of jump and dip are not uniform, which makes it hard to estimate the future trend of jump and dip. To solve this problem all non-homogenous jump and dip periods have been homogenised to a 24 month period and graphed in Fig. 8. As can be seen in Fig. 8 the jump and dip trend of the gold price is similar to a sinusoidal trend. The size of the jump and dip, however, were different in periods. For example from October 1974 to November 1984, the gold price increased by more than 80% of the long-term trend, equivalent to a $200/oz increase in that period. Nevertheless, in a second jump from September 2007 until now, the gold price increased by 50% or around $250/oz more than the long-term trend. Consequently, it is expected that in the next 10 years the gold price will continue in jump for a couple of years and after that it will return to its long-term trend.

Forecasting the gold price for the next 10 years

Initially, this section validates the new model. The model uses the data from January 1968 to December 1998 and it then predicts the gold price from January 1999 to December 2008. To predict the gold price in this time frame, parameters in Eq. (3) have been estimated to compute the three components of the equation. Fig. 9 illustrates the prediction of gold prices by the new

Table 5
Augmented Dickey Fuller results for testing stationary in nominal gold price and first difference from 1968 to 2008.
Source: Data from KITCO (2009) and modellings computed in Eviews.

Variable	Gold price			First difference of gold price		
ADF test	Intercept and Trend	Intercept	None	Intercept and trend	Intercept	None
t-statistic	−1.96	−0.97	0.40	−5.54	−5.52	−5.33
5% critical value	−3.42	−2.87	−1.94	−3.42	−2.87	−1.94
Probability value	0.62	0.76	0.80	0.00	0.00	0.00
Conclusion		Nonstationary			Stationary	

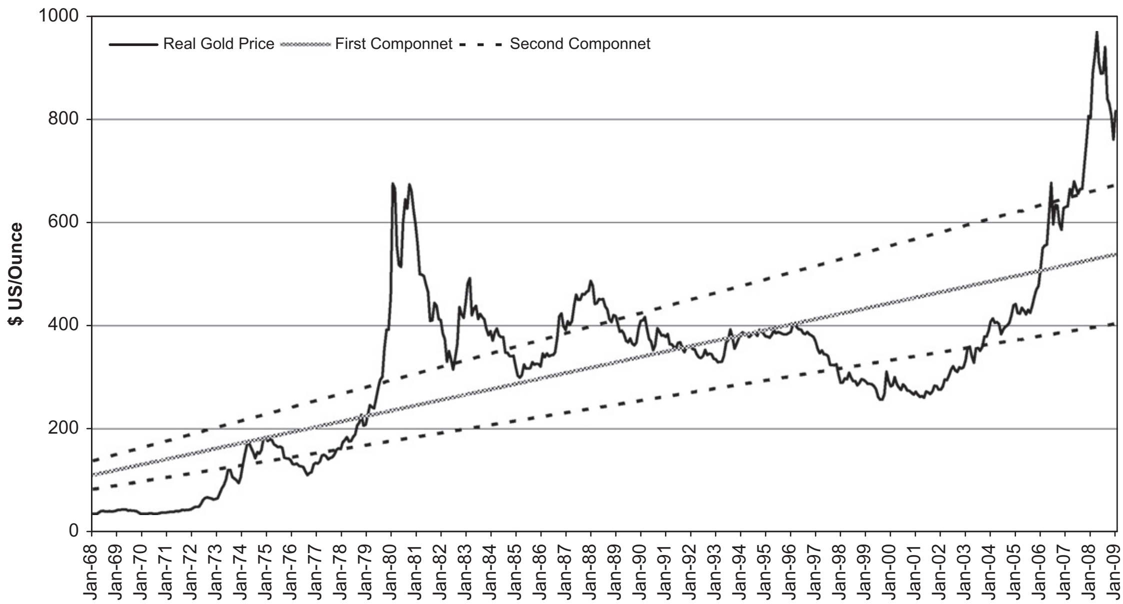

Fig. 6. The monthly historical trend of nominal gold price, first component and second component of TSP model from January 1968 to December 2008.

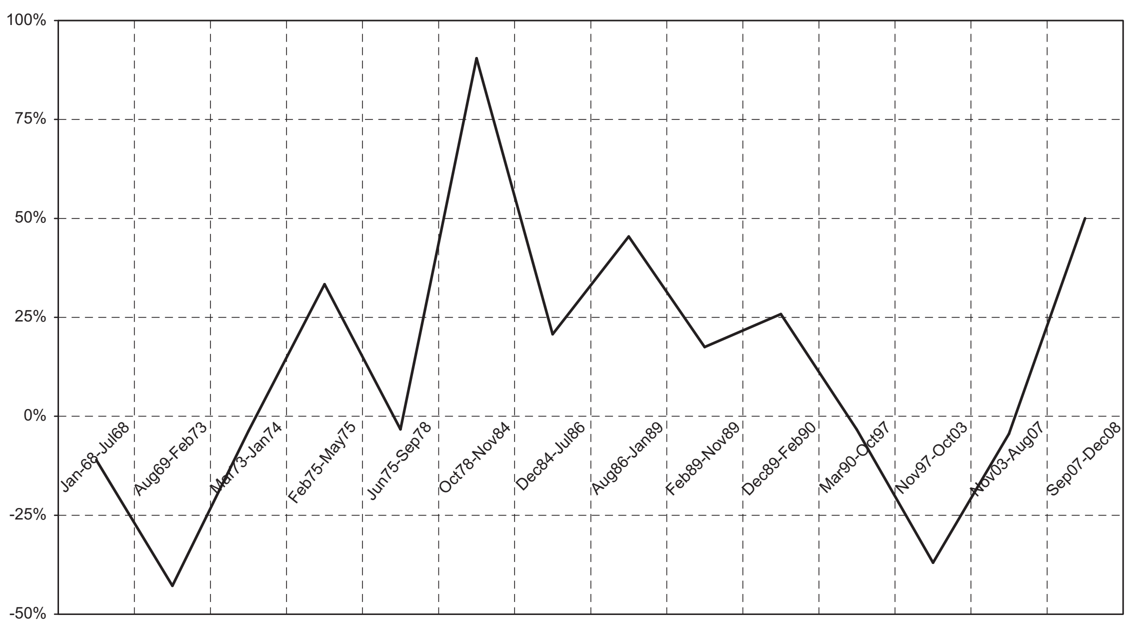

Fig. 7. The percentage of jump and dip periods for monthly historical nominal gold price from January 1968 to December 2008.

model from January 1999 to December 2008 versus real data. As can be seen in the following Fig. 9, the model has predicted that a dip period exists until 2003 and then the gold price goes back to its long-term trend until 2007 after which it jumps. As can be seen, the trend of gold price predictions by the new model is very close to the actual gold price data.

In this section, the paper uses the historical gold price from January 1968 to December 2008 to anticipate gold prices for the next 10 years. The first component in the model is the long-term trend reversion component. This component demonstrates that the gold price should be reverting to the historical long-term trend. According to historical data, Eq. (3) is estimated in Table 7. As can be seen in the following table, the first component has computed around \$1.10. This means the gold price on average has increased \$1.10 per ounce monthly over last 40 years. The model assumes that the gold price in the future will increase in a similar manner to the historical tend. This component shows the gold price in the future is reverting to this long-term trend and then the second and third components are catching the fluctuations. Furthermore, White's test and Durbin Watson test prove that the model developed has no heteroscedasticity and autocorrelation problems.

The second term is the diffusion component, which multiplies random numbers of standard normal distribution for the jumps and dips volatility. The second component has been calculated around 25% of current gold price in each month. The gold price in the next month will increase or decrease by around 25% of the first component. The second component has two advantages. First, the random movements would be between the range of the second component. Second, this range helps the model to

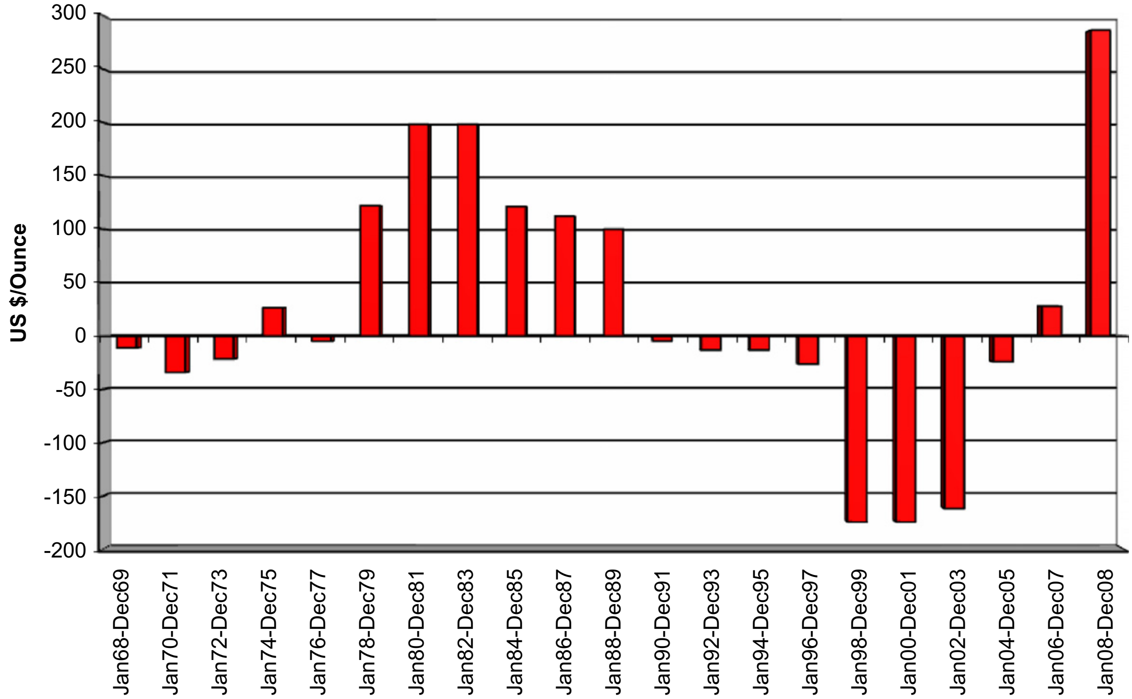

Fig. 8. The differential of jump and dip long-term trend of monthly historical nominal gold price from January 1968 to December 2008.
Source of data: KITCO (2009).

Table 6
The status of jump and dip periods for nominal gold price from January 1968 to December 2008.
Source: Data from KITCO (2009) and modelling in Eviews.

Period		Duration (months)	Status	Average of gold price (US$/oz)	Average of trend reversion (US$/oz)	Jump/dip size (US$/oz)	Jump/dip size (percentage)	Max gold price (US$/oz)	Min gold price (US$/oz)
From	To								
Jan-68	Jul-69	19	No jump/dip	40	45	−5	−11%	43	35
Aug-69	Feb-73	43	Dip	45	79	−34	−43%	74	35
Mar-73	Jan-74	11	No jump/dip	105	109	−4	−4%	129	84
Feb-74	May-75	16	Jump	166	124	42	33%	184	143
Jun-75	Sep-78	40	No \jump/dip	150	155	−5	−3%	212	110
Oct-78	Nov-84	74	Jump	416	218	198	90%	675	206
Dec-84	Jul-86	20	No jump/dip	327	271	56	21%	349	299
Aug-86	Jan-89	30	Jump	434	298	135	45%	486	377
Feb-89	Nov-89	10	No jump/dip	376	320	56	17%	394	362
Dec-89	Feb-90	3	Jump	412	328	84	26%	417	409
Mar-90	Oct-97	92	No jump/dip	368	380	−13	−3%	405	323
Nov-97	Oct-03	72	Dip	297	471	−174	−37%	379	256
Nov-03	Aug-07	46	No jump/dip	513	536	−24	−4%	679	383
Sep-07	Dec-08	16	Jump	856	571	286	50%	968	713

accommodate jump and dip within the third component. The third component is the most important component as it is used to predict jump/dip and it will add in the two previous components in predicting for the future.

The third component demonstrates jump/dip period. Table 7 shows that during a dip period the gold price goes down at $18 per ounce which is less than the minimum amount of the second component. Table 7 also shows that during jump periods the gold price rises above $20 per ounce which is the top of the maximum figure of the second component. To predict the third component, the model investigates the last 40 years of historical data. As can be seen in Fig. 7 the gold price has two big jumps. The first one was from October 1978 to November 1984, and the second jump had already occurred by September 2007. Moreover, Fig. 7 depicts two dips as well. The first dip was from August 1969 to February 1973 and the second dip occurred 25 years later and was from November 1997 to October 2003. During the remaining time periods, the gold price reverted to its long-term trend for nearly 20 years. Therefore, the model assumes that the second jump is similar to the first jump and will continue between 6 and 7 years. The gold price in October 2008 is still on the jump and this jump will be continued until the end of December 2014. After that, the gold price will revert to the long-term trend up to end of 2018. Most of the previous models ignore this component and assume a wide range of volatility in the mean reversion component. This model however considers the size of jump and dip in the forecasting model. All three components are summed up and illustrated in Fig. 10.

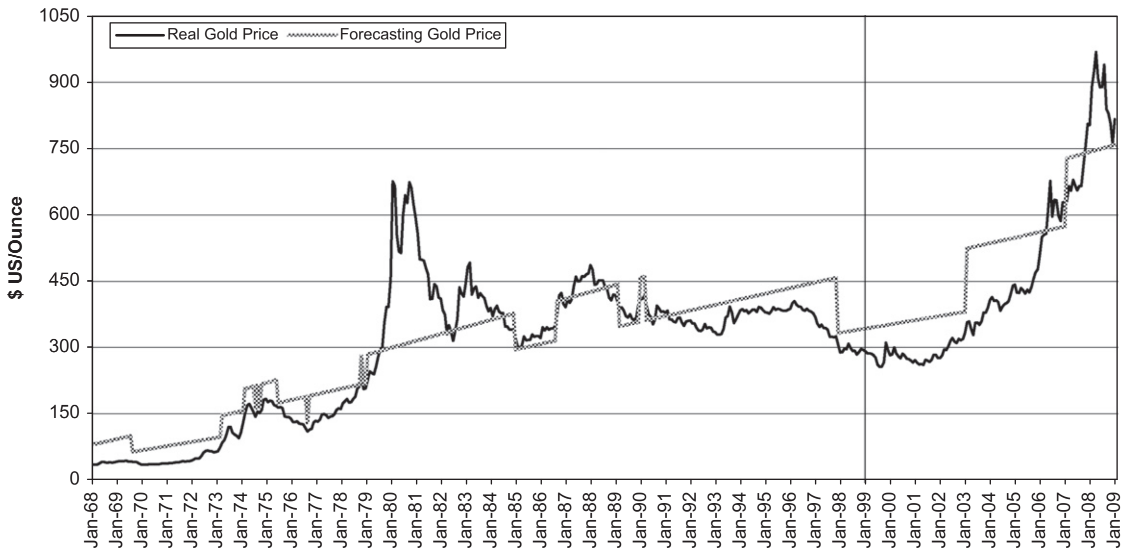

Fig. 9. The monthly historical and future forecasting trend of nominal gold price from January 1968 to December 2008.
Source of data: KITCO (2009).

Table 7
The results of three different components for nominal gold price from January 1968 to December 2008.
Source: Data from KITCO (2009) and modellings computed in Eviews.

Variable	Constant	First component	Second component	Third component	
		Time chronologically	±25% volatility	Dummy variable for Dip	Dummy variable for Jump
Coefficient	33.37	1.12	(±25%) (first component)	−18.25	20.74
t-Student	49.22	26.98	–	−2.25	3.99
Std-error	0.67	0.04	–	8.11	5.19
R-squared	0.98		D.W	1.89	

Fig. 10. The monthly historical and future forecasting trend of nominal gold price from January 1968 to December 2018.
Source of data: KITCO (2009).

Table 8 used root mean squared error (RMSE) and mean absolute error (MAE) to compare the forecasting error by the new model and ARIMA model. These two forecasting error statistics depend on the scale of the dependent variables. They should be used as relative measures to compare forecasts across the different models. The smaller the forecasting error, the better the model forecasting is. As can be seen in Table 7, RMSE and MAE in the new model are smaller than the ARIMA model for gold price. Consequently, it is clear that predicting using the new model is an improvement over the ARIMA model.

Table 8
The results of RMSE and MAE test for new model and ARIMA for nominal gold price from 1968 to 2008.

Model\test	RMSE	MAE
New model	116.52	88.26
ARIMA	127.98	97.72

Conclusion

The first section of this paper analyses the demand, supply and price of the gold market. Analysing the gold supply showed that around 160,000 tonnes of gold has been mined in history up to the end of 2008. Gold demand by jewellery, industrial and central bank reserves equate to approximately 100,000, 30,000 and 30,000 tonnes, respectively. A significant proportion of the demand side of gold is attributed to jewellery, which can in turn be injected into the supply side.

From 1833 to 1968 the gold price remained steady for more than a century, then it started to fluctuate. The paper presents the role of important variables such as oil price and inflation in the gold market. There is a high correlation between gold and oil prices at around 85%. However, the study showed the relationship between the gold price growth and cumulative inflation was around -9% over the last four decades, and there was no significant relationship between gold price and inflation. The ratio of the prices of one ounce of gold to one barrel of crude oil was calculated to be approximately 11 in 1968 and 2008. This means 11 barrels of crude oil is equivalent to one ounce of gold in 1968 and 2008. Consequently, this index shows that the range of gold prices to oil prices remained stable over the long-term.

In the following section a unit root test was applied to the long-term monthly gold price. This concluded that the gold price in the long-term is nonstationary. A new model proposed a trend stationary process to solve the nonstationary problems in previous models. The advantage of this model is that it includes the jump and dip components into the model as parameters. The behaviour of historical commodities prices includes three different components: long-term reversion, diffusion and jump/dip diffusion. The proposed model was validated with historical gold prices. The model was then applied to forecast the gold price for the next 10 years. The results indicated that, assuming the current price jump initiated in 2007 behaves in the same manner as that experienced in 1978, the gold price would stay abnormally high up to the end of 2014. After that, the price would revert to the long-term trend until 2018.

Acknowledgments

The authors are pleased to acknowledge the contribution made by Peter Knights, Micah Nehring Shuxing Li and Jade Little towards the completion of the manuscript.

References

Aggarwal, R., Lucey, B.M., 2007. Psychological barriers in gold prices? Review of Financial Economics 16 (2), 217–230.
Ahrens, W.A., Sharma, V.R., 1997. Trends in natural resource commodity prices: deterministic or stochastic? Journal of Environmental Economics and Management 33, 59–74.
Batchelor, R., Gulley, D., 1995. Jewellery demand and the price of gold. Resources Policy 21 (1), 37–42.
Berck, P., Roberts, M., 1996. Natural resource prices: will they ever turn up? Journal of Environmental Economics and Management 31, 65–78.
Bessembinder, H., Coughenour, J.F., Seguin, P.J., Smoller, M.M., 1995. Mean reversion in equilibrium asset prices: evidence from the futures term structure. The Journal of Finance 50 (1), 361–375.
Black, F., Scholes, M., 1973. The pricing of options and corporate liabilities. The Journal of Political Economy 81 (3), 637–654.
Blanco, C., Choi, S., Soronow, D., 2001. Energy price processes used for derivatives pricing and risk management. Commodities Now, 74–80 March.
Blanco, C., Soronow, D., 2001a. Jump diffusion processes-energy price processes used for derivatives pricing and risk management. Commodities Now, 83–87 September.
Blanco, C., Soronow, D., 2001b. Mean reverting process-energy price processes used for derivatives pricing and risk management. Commodities Now, 68–72 June.
Blose, L.E., 1996. Gold price risk and the returns on gold mutual funds. Journal of Economics and Business 48 (5), 499–513.
Blose, L.E., Shieh, J.C.P., 1995. The impact of gold price on the value of gold mining stock. Review of Financial Economics 4 (2), 125–139.
Bordo, M.D., Dittmar, R.D., Gavin, W.T., 2007. Gold, fiat money, and price stability. The B.E. Journal of Macroeconomics 7 (1), 26 Article.
Craig, J.R., Rimstidt, J.D., 1998. Gold production history of the United States. Ore Geology Reviews 13 (6), 407–464.
Dias, M.A.G., Rocha, K.M.C. 2001. Petroleum concessions with extendible options using mean reversion wiht jumps to model oil prices. In Working Paper. Institute for Applied Economic Research from Brazilian Government, Rio de Janeiro.
Doggett, M., Zhang, J., 2007. Production trends and economic characteristics of Canadian gold mines. Exploration and Mining Geology 16 (1–2), 1–10.
Fama, E.F., 1965. The behavior of stock market prices. The Journal of Business 38 (1), 34–105.
Fortune, J.N., 1987. The inflation rate of the price of gold, expected prices and interest rates. Journal of Macroeconomics 9 (1), 71–82.
Govett, M.H., Govett, G.J.S., 1982. Gold demand and supply. Resources Policy 8 (2), 84–96.
Gujarati, D., 2003. Basic Econometrics. McGraw Hill, Boston.
IEA, 2008. Spot Prices: Paris and Washington, DC. Organisation for Economic Co-operation and Development, International Energy Agency.
Inflation Data, 2009. Financial Trend Forecaster. ⟨http://www.inflationdata.com/inflation/⟩.
Kaufmann, T.D., Winters, R.A., 1989. The price of gold: a simple model. Resources Policy 15 (4), 309–313.
KITCO, 2009. Gold Historical Charts. ⟨http://www.kitco.com/charts/⟩.
Klass, D.L., 1998. Biomass for Renewable Energy, Fuels, and Chemicals. Academic Press, San Diego.
Laughton, D.G., Jacoby, H.D., 1993. Reversion, timing options, and long-term decision-making. Financial Management 22 (3), 225–240.
Laulajainen, R., 1990. Gold price round the clock : technical and fundamental issues. Resources Policy 16 (2), 143–152.
Lee, J., List, J.A., Strazicich, M.C., 2006. Non-renewable resource prices: deterministic or stochastic trends? Journal of Environmental Economics and Management 51, 354–370.
Mahdavi, S., Zhou, S., 1997. Gold and commodity prices as leading indicators of inflation: tests of long-run relationship and predictive performance. Journal of Economics and Business 49 (5), 475–489.
Merton, R.C., 1973. Theory of rational option pricing. The Bell Journal of Economics and Management Science 4 (1), 141–183.
Mills, T.C., 2004. Statistical analysis of daily gold price data. Physica A 338 (3–4), 559–566.
Mueller, M.J., Gorin, D.R., 1985. Informative trends in natural resource commodity prices: a comment on Slade. Journal of Environmental Economics and Management 12, 89–95.
Parisi, A., Parisi, F., Díaz, D., 2008. Forecasting gold price changes: rolling and recursive neural network models. Journal of Multinational Financial Management 18 (5), 477–487.
Patterson, K., 2000. An Introduction to Applied Econometrics: A Time Series Approach Houndmills. Macmillan, Basingstoke.
Press, S.J., 1967. A compound events model for security prices. The journal of Business 40 (3), 317–335.
Rockerbie, D.W., 1999. Gold prices and gold production: evidence for South Africa. Resources Policy 25 (2), 69–76.
Seifritz, W., 2003. An endogenous technological learning formulation for fossil fuel resources. International Journal of Hydrogen Energy 28, 1293–1298.
Selvanathan, S., Selvanathan, E.A., 1999. The effect of the price of gold on its production: a time-series analysis. Resources Policy 25 (4), 265–275.
Shafiee, S., Topal, E. 2007. Econometric forecasting of energy coal prices. In: Proceedings of the 2007 Australian Mining Technology Conference. CRC Mining, Western Australia, pp. 173–179.
Shafiee, S., Topal, E., 2008a. An econometrics view of worldwide fossil fuel consumption and the role of US. Energy Policy 36 (2), 775–786.
Shafiee, S., Topal, E., 2008b. Introducing a new model to forecast mineral commodity price. In: Proceeding of First International Future Mining Conference & Exhibition. The University of New South Wales, Sydney, Australia, pp. 243–250.
Shafiee, S., Topal, E., 2009. When will fossil fuel reserves be diminished? Energy Policy 37 (1) 181–189.
Shafiee, S., Topal, E., 2010. A long-term view of worldwide fossil fuel prices. Applied Energy 87 (3), 988–1000.
Slade, M.E., 1982. Trends in Natural-resource commodity prices: an analysis of the time domain. Journal of Environmental Economics and Management 9, 122–137.
Slade, M.E., 1985. Noninformative trends in natural resource commodity prices U-shaped price paths exonerated. Journal of Environmental Economics and Management 12, 181–192.

Slade, M.E., 1988. Grade selection under uncertainty: least cost last and other anomalies. Journal of Environmental Economics and Management 15, 189–205.
Slade, M.E., 1998. Managing Projects Flexibly: An Application of Real-Option Theory. In Discussion Paper No.: 98-02. The University of British Columbia, Vancouver.
Tully, E., Lucey, B.M., 2007. A power GARCH examination of the gold market. Research in International Business and Finance 21 (2), 316–325.
USGS, 2008. Mineral Commodity Summaries 2008. In US Department of the Interior & US Geological Survey: United States Government Printing Office (US Geological Survey), Washington.
Varela, O., 1999. Futures and realized cash or settle prices for gold, silver, and copper. Review of Financial Economics 8 (2), 121–138.
WGC, 2008. World Gold Council Publications Archive. www.gold.org: World Gold Council.
WGC, 2009. Gold investment digest. www.gold.org: World Gold Council.