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School of Business
Finance

GOLD INVESTMENTS AND SHORT- AND LONG-RUN PRICE DETERMINANTS OF THE PRICE OF GOLD

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ABSTRACT

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This study examines the short- and long-run price determinants of the price of gold. Second, it investigates the possibilities of gold investing.

Monthly data consisting of US and world consumer price indexes, US and world inflation and inflation volatility, beta of gold, gold lease rate, credit default risk and US-world exchange rate index from December 1972 to August 2006 is used in this study. Cointegration regression techniques are used to develop a model and find the key determinants for the price of gold. We also examined the literature to find out what different investment methods and instruments exist on the gold markets.

The empirical results of this study support the results of previous studies. We found further evidence that gold can be regarded as a long-run hedge against the inflation and that the price of gold moves inline with the general price level. However, the movements in the nominal price of gold are dominated by short-run influences and that the long-run relationship has less impact at any given time. We also found that gold is readily available to investors in all the major markets and a plentiful of instruments can be used.

TIIVISTELMÄ

Tekijä:	Lampinen, Anssi
Tutkielman nimi:	Kultaan sijoittaminen, sekä lyhyen- ja pitkän aikavälin kullan hintaan vaikuttavat tekijä
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Tämän tutkielman tavoitteena on tutkia tekijöitä jotka vaikuttavat lyhyellä ja pitkällä aikavälillä kullan hintaan. Toiseksi tutkielmassa selvitetään mitä eri sijoitusmahdollisuuksia löytyy kultaan sijoitettaessa.

Aineistona käytetään kuukausitasoista dataa Yhdysvaltain ja maailman hintaindekseistä, Yhdysvaltain ja maailman inflaatiosta ja inflaation volatiliteetista, kullan beetasta, kullan lainahinnasta, luottoriskistä ja Yhdysvaltojen ja maailman valuuttakurssi indeksistä joulukuulta 1972 elokuulle 2006. Yhteisintegraatio regressiotekniikoita käytettiin muodostamaan malli jonka avulla tutkittiin päätekijöitä jotka vaikuttavat kullan hintaan. Kirjallisuutta tutkimalla selvitettiin miten kultaan voidaan sijoittaa.

Empiiriset tulokset ovat yhteneväisiä edellisten tutkimusten kanssa. Tukea löytyi sille, että kulta on pitkän ajan suoja inflaatiota vastaan ja kulta ja Yhdysvaltojen inflaatio liikkuvat pitkällä aikavälillä yhdessä. Kullan hintaan vaikuttavat kuitenkin lyhyen ajan tekijät pitkän ajan tekijöitä enemmän. Kulta on myös sijoittajalle helppo sijoituskohde, koska se on hyvin saatavilla markkinoilla ja eri instrumentteja on lukuisia.

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1. INTRODUCTION

1.1 Background

Demand for gold can be split into two categories. First, there is demand for physical gold, for example jewellery, coins and electronics. Then there is the demand for investment purposes. Governments, institutional and private equity investors invest in gold for various reasons. These reasons vary from hedging against inflation to speculative investing. In this thesis, we concentrate on the investment demand of gold, but to fully understand the determinants of the price of gold, we also need to look into the physical demand part.

Despite the passionate interest for gold throughout the history of mankind and the rising interest of late, investing in gold has not been overly popular in the recent years. In December 2005, gold broke the $500 barrier for the first time since 1982. After that, gold has continued to rise in value and has been as high as $752 on 12th of May 2006. The price of gold has since settled into $650 region. Even though the recent price rally of gold has been phenomenal, in September 2001 the price of gold was as low as $257 and a downfall of two decades had preceded it. In the early 80's, the price of gold was over $800 for some days and for almost 20 years the price of gold was in a stalemate.

In 1833 the price of gold was $20.65 per ounce, valued approximately $415 in 2005 dollars. In 2005 the price of gold was $445. A nominal increase of about $224 but barely any increase in the real value. The price of gold fluctuates a lot in the short-run, but in the long-run, it has been fairly steady and it has been found to follow the general price level quite closely. Levin and Wright (2006) have found that in the long-run, a one percent increase in the US-price level has lead to an even increase in the price of gold. Gosh et al. (2004) have also found that the price elasticity of gold, compared to the US Consumer Price Index (CPI), is 1.1, which leads to a conclusion that gold is a long-run hedge against inflation. On the other hand, studies suggest that gold is not an effective hedge against inflation in the short-run (Aggarwal, 1992).

Hiller et al. (2006) studied the role of gold and commodities on equity markets. They discovered that in period 1976-2004 gold had a small negative correlation with S&P 500 index and a small positive correlation with EAFE[1] index. They found that portfolios which had 5 to 10 per cent gold, performed better than portfolios without gold. Jaffe (1989) also proved that the low correlation of gold with stocks grants it a place in a well diversified portfolio.

Historically, investing in gold has been connected with fears of inflation or political risks. However, money markets are not showing any symptoms of incoming inflation at the moment. Interest rates have been all time low in The United States and Europe for a long time and inflation has been in the region of 3% in US and 2% in Europe.

However, Levin and Wright (2006) see the US debt as a possible cause of future inflation. US debt has risen to 6.4% of GDP in year 2005. The current account deficit is financed by incoming foreign investments in the USA. But if the foreigners would reduce their investments in dollar-denominated investments, could dollar see a sharp decline in value. This would lead to a decline in the stock prices and a rise in interest rates and a fall in real estates prices. As a consequence, it could launch the US economy into a downturn.

[1] MSCI EAFE index is recognized as the most popular benchmark in the USA to measure international equity performance overseas. It comprises 21 MSCI country indices from Europe, Australasia and the Far East. (MSCI, 2006)

Other sing of a possible downfall of dollar comes from China. Levin and Wright (2006) predict that the rising dollar reserves of China pose a serious threat to the dollar. China has dollar reserves of $818.9 billion and they rise at a fast rate, 34% in the year 2005.

Jarret (2005) gives five reasons why the account deficit of US will grow and dollar will plummet:

1) Imports are half as large as exports.
2) Imports continue to grow at faster pace than exports if the economy of US expands faster than its trade partners.
3) The investment income balance is likely to deteriorate over time in view of the spread of returns between those earned by US residents on their investments and the average yield on foreign investments in the US.
4) The slow speed of ageing in the United States will take its toll on US account in the coming decades.
5) Most financial decisions to improve the balance have inflicted second-round effects that have offset the initial helpful shock.

According to Levin and Wright (2006), the public opinion is that the dollar has to depreciate. However, the estimates vary from a modest decline to as much as 90%. This decline will affect the prices of financial assets greatly, including gold.

Also the long-term sustainability of Euro is in doubt according to Levin and Wright (2006). The creditability of Euro has suffered from the failure to agree a European Constitution that could provide a formal ownership of the currency. Also France and Germany have for the last four years broke the growth and stability pact rule that requires the government budget deficit to be less than 3% of GDP.

1.2 Objectives and methodology

In this thesis, we study the determinants of the price of gold using short-run and long-run models for the price of gold, comprised from different macro economical factors. The results will be contrasted to findings of previous studies on the price of gold. Also, gold is one of the most liquid assets and probably more so in the war time, but investing in it can be quite difficult compared to other equities. This is especially the case in Finland for other than big institutional investors. It is therefore interesting to dwell into the different methods of investing and give the reader an idea on how one can invest in gold. Research questions are as follows:

Q1. What are the different methods for investing in gold and what is their availability?
Q2. Can gold be regarded as a long-run hedge against inflation?
Q3. What are the short-run and long-run determinants for the price of gold?

The first question will be addressed by researching the available literature and the last two questions will be examined by using cointegration regression techniques.

1.3 Limitations

This study concentrates on the short-run and long-run price determinants for the price of gold. It will also study the investment side. However, we do not compare gold's return or risk to other instruments, but concentrate instead on explaining what kind of instruments there are available to an investor interested in investing in gold.

Data series pose limitations on the chosen study period for our modelling process. There is daily price data available on gold and silver from the early seventies, but not for other determinants, which restricts the time frame of the study to 1973-2006 for the full model and to 1989-2006 for the sub-period model. We also excluded some variables used in other studies because they were not readily available, most notably world income and a country risk variable.

1.4 Structure

The remainder of the thesis is structured as follows. Chapter 2 covers the history of gold and its place in the world economy. Chapter 3 presents a literature review on the previous studies and empirical results on the subject of this study. Data and methodology is presented in chapter 4 and the empirical results of this study are covered in chapter 5. Chapter 6 concludes the thesis.

2. GOLD IN WORLD ECONOMY

2.1 A short history on gold production

Gold was one of the first metals humans excavated. This was party because gold was found in pure form in the nature, it was easily workable by artisans and gold had aesthetic value. History of gold began in Egypt and Nubia some 5000 years ago. These regions have been the biggest gold producers throughout most of the history.

In 1500 BC, gold became the recognized standard medium of exchange for international trade in the Middle-East and made Egypt a wealthy nation. About 400 years later, 1091 BC, little leaflets of gold became legalized money in China. It took another 450 years until Lydia minted their own gold coins and in 58 AD, the Romans followed suit. By the time England chose a monetary system which was based in gold and silver in 1377 AD, gold had taken its place amongst silver as a medium of exchange.

When Egypt and the Roman Empire were in their full glory, gold was produced in the region of 1 tonne annually. The production of gold fell back under less than a tonne annually in the Dark- and Middle Ages (500 - 1400 AD). In 15th century, when the gold coast of Africa produced about 5 to 8 tonnes annually, gold production grew notably. The discovery of America opened new possibilities for gold producers and Brazil started to produce gold in the early 18th century. The second era of gold production started in 1848 with the discovery of Sutter's Mill gold on the American River. This started the gold rush and output from California soared, reaching 77 tonnes in 1851. Gold findings in Australia the same year raised world production to 280 tonnes in 1852. In 1898 South Africa took the lead in gold production and since produced about 40% of all the gold ever produced. (World Gold Council, 2006a)

2.2 Gold standard

Gold standard is a monetary system where the standard economic unit of count is a weight of gold. It is ideally fixed and not subject to change. The amount of paper money issued is also either tightly or loosely tied to the central bank gold reserve.

Under gold standard, currency is in either coins struck in gold or paper money which the issuer is guaranteed to redeem in gold for and amount ideally fixed in advance. Gold standard can be either internal or international. In internal gold standard, the holders of paper money can redeem it for gold and in international gold standard, only certain entities, for example central banks, can demand the exchange. All the countries in gold standard have fixed exchange rates with each other. Amongst other things, it is one of the advantages of gold standard. For example, countries can not press more money than they have gold in their reserves and this prevents inflation and gives more creditability to the monetary policy.

England was the first nation to adapt full gold standard in 1844 and Bank of England notes, fully backed by gold, were the legal standard at that time. It took almost 30 years before the next nation, Germany, chose gold standard as their monetary system, in 1871. Germany funded their gold standard with gold shipped from South-Africa. Soon after this, the rest of the Europe, including Finland, adapted gold standard. By the year 1890, most of the word was in gold standard.

The period from 1880 to 1913 is often called the "classical gold standard." It featured a core of nations, led by the Bank of England. Fixed gold price and continuous convertibility were sustained by the core nations and central banks were obliged, in theory, to adjust interest rates to maintain fixed exchange rate between the domestic currency and gold. However, the gold standard was not perfectly fixed. Central banks had varying degrees of competition and cooperation. There were loosely tied monetary unions and tightly tied monetary unions where the currencies were tightly interlocked. The main gold standard of Europe was maintained by the Bank of England. The Bank of England adjusted interest rates to maintain the price relationship of the pound to other major currencies. During the peak period of the gold standard, composed of 360 months, the Bank of England bank rate was adjusted over 200 times. Amongst others, Russia and the United States allowed significant internal deviations from gold standard. The US issued silver backed currency and Russia printed paper money and minted coins. The paper money in Russia was selling at 60% to 75% of specie.

As gold standard was becoming more widely used, its network effects grew. Countries outside the gold standard had a hard time getting credit and exporting their goods and this attracted more countries to use gold backed currencies. Also, one of the main benefits of gold standard was the reduction in inflation volatility. This helped companies in planning their investments and other expenses and made the gold standard more popular.

With the outbreak of World War I, the United Kingdom had to make series of decisions which led to its leaving from gold standard in 1914. This happened, because the war effort was being funded by printing more money that could be backed by gold and this led to inflation. After the war, the Great Britain and the US tried to go back to the gold standard, eventually resulting in giving up in 1931 by the Great Britain and in 1933 by the US. However, international institutions were able to trade US dollar to gold until 1974. This convertibility gave creditability to the US dollar during the Bretton Woods system. To prevent speculation, the citizens of the United States were prohibited to own gold during Bretton Woods system. This restriction was removed in 1974.

Gold standard has had many supporters after its fall, the former US Federal Reserve Chairman Alan Greenspan amongst the most famous. However, the common opinion at the moment is that gold standard is not a viable alternative for the current system. The reasons why gold standard was so successful for so long are the Great Britain's leading role in the 1900 century and its role in forcing the rules upon other members of gold standard. This led to a universal acceptance of the gold standard. And while the gold standard itself did not give enough flexibility to monetary policy to avoid shocks, wages and prices were flexible enough. (Bordo, 1993)

2.3 Gold trading

After the World War II, gold price was fixed to $35 per ounce. This gave creditability to the US dollar during the Bretton Woods system. In the late 1960's, dollar suffered from serious devaluation and inflation expectations and this lead into gold having two prices in 1968. One price was for private trade and the other for trade between central banks. In 1971 the pressure was so high that the dollar gold fix was broken at $42.22 per ounce.

Figure 1 presents the price of gold from 1971 to 2006. From the figure, one can see how the oil crisis, floating exchange rates and the silver cornering have affected the price of gold in late 70's and early 80's, right after the link was broken between gold and US dollar. This rapid price rally was followed by a decline of almost 20 years, but in the last two years, this decline has changed to a rapid price rally once more. (Michaud, Michaud & Pulvermacher, 2006)

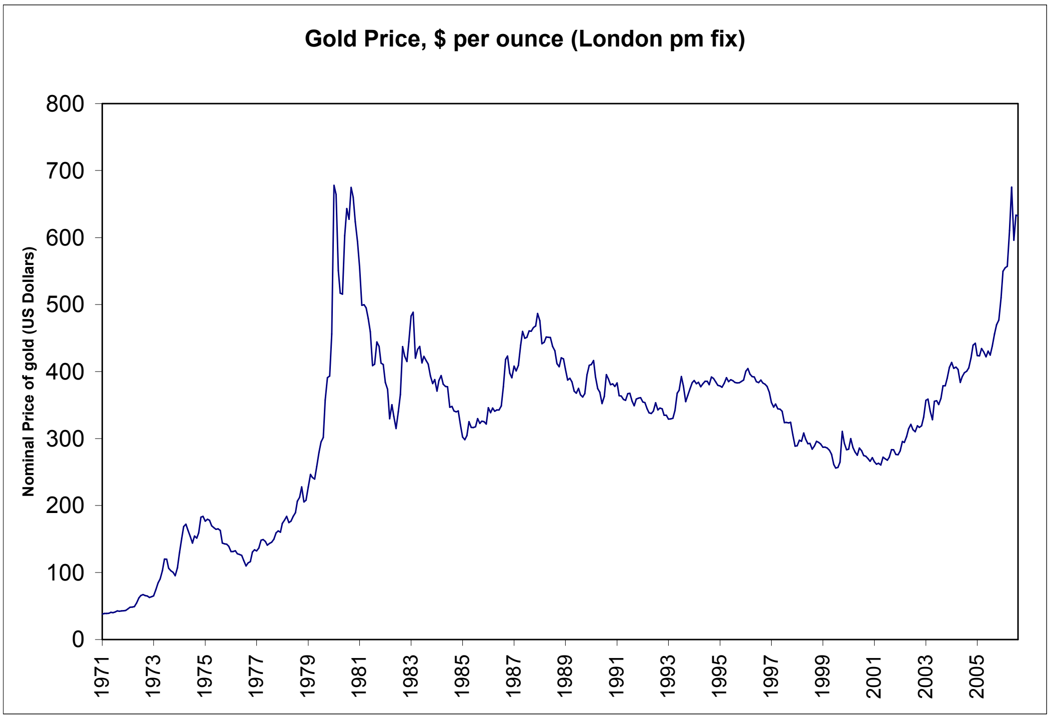

Figure 1. Price of gold from the breaking of dollar gold fix to present time, 1971-2006.

2.3.1 The role of central banks

Central bank agreement on gold (CBGA) was signed in 26.9.1999 by the central banks of EU and Switzerland, excluding Denmark and Greece. The agreement emphasizes the importance of gold as a reserve asset.

1. The central banks agreed on limiting the sales of gold and only to follow thru the deals that were already agreed on. These sales were however not allowed to exceed 400 tonnes a year and 2 000 tonnes in the following 5 years. After five years, the agreement was to be re-evaluated.
2. Countries also agreed to limit their gold leases to the level they have previously leased gold and not acquire more gold to their reserves. (European Central Bank, 1999)

The USA, IMF and BIS promised to honour the agreement on their part and not to sell or buy gold while the agreement was valid. After this promise, the agreement covered 85% of all reserve gold. (Cross, 2000)

The agreement was renewed in 8.3.2004 and it covers the following 5 years. The Great Britain did not sing the new agreement, but made a statement that it has no intention of selling or buying gold in the near future. Greece, who did not sign the first agreement, signed the second one. The second agreement limited the sales of gold to 500 tonnes a year and 2 500 tonnes in the five year period. Gold leases would stay in the same limits as in the first agreement. (European Central Bank, 2004)

The central banks signalled in the agreement that gold still had an important role in their reserve policies, even though their reserves are in a decline. These central banks have approximately 35% of their reserves in gold, while the optimal amount has been recognised to be around 10% to 12% (Mozhaiskov, 2004). According to Deputy Chairman Oleg V. Mozhaiskov from the Bank of Russia, the gold stock is the international payment reserve for the whole country, for the state authorities, private companies and corporations, as well as individual citizens. Like any reserve, it needs to be conserved, in terms of both actual physical form and its value. To a lesser extent, one has to be concerned about its liquidity, or more precisely, market price developments.

The agreement affected gold price because it was believed that the massive gold reserves of central banks were an unlimited source of lent gold. This led to a price ceiling for gold and also for lent gold. If the price of gold would go up, more gold would make its way to the market from the reserves and the price would drop back down. (Cross, 2000)

Central banks hold 18% of all the worlds gold in the end of 2005. Bank of Finland has 49.1 tonnes of gold in its reserves and it covers 13.8% of all the Finnish reserves. The United States has the most gold in their reserves, 8 133.5 tonnes and it covers 78.5% of their reserves. These statistics are provided by International Monetary Fund's International Financial Statistics database. Figure 2 shows how the central bank gold reserves are spread amongst different regions.

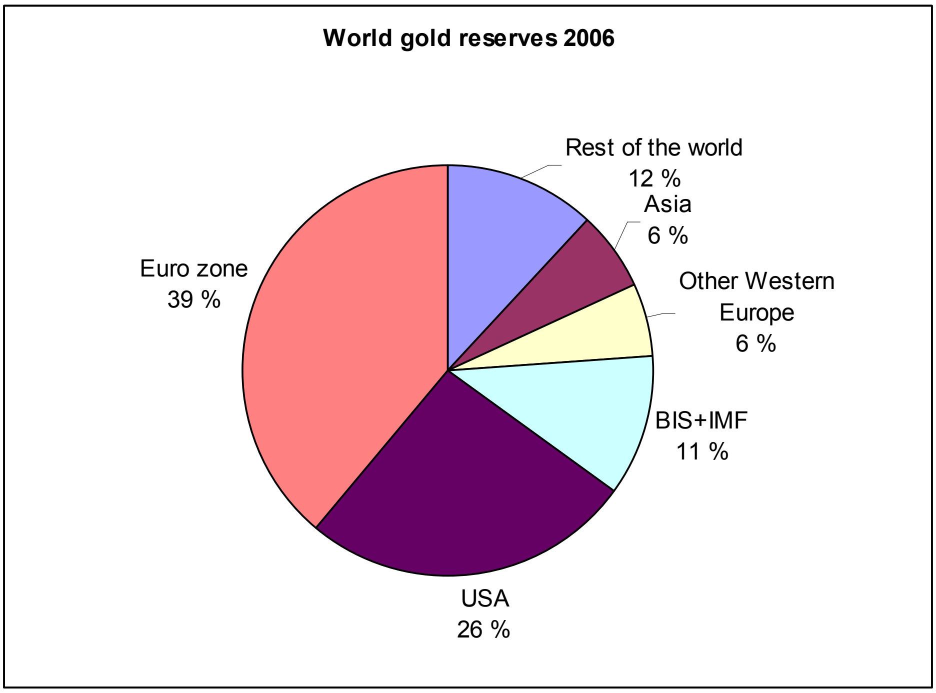

Figure 2. World gold reserves in 2006 held by the central banks.

According to The World Gold Council (2006b), central banks hold gold reserves because:

- **Gold provides economical safety.** Currencies are prone to bad decisions made by governments and their value change accordingly. Price of gold is unaffected by these decisions. Fiat money[2] could also see some rough devaluation when its value as reserve money would collapse.

- **Gold provides physical safety.** History has shown that many countries frequently impose exchange controls affecting the free transfer of their currencies or, at the worst, total asset freezes which prevent other countries accessing their cash or securities.

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[2] Fiat money is a government issued note which value is not tied to any specie but its value is backed by the creditability of the issuer.

- **Unexpected changes in the world monetary system** could lead to a collapse in the value of the reserves. No monetary system can last forever. War, hyperinflation, world wide currency crisis or any other major crisis could lead to full or partial collapse of the present system. In this case, gold acts as an option for uncertain future.

- **World wide confidence** towards gold is big. Public opinion polls show that if a country has gold in their reserves, their citizens have more trust their money.

- Gold offers **diversification benefits** to central banks portfolios.

- **Income** from lending gold has been notable.

- Gold acts also as a **store of value** against inflation.

2.3.2 London gold fix

London has been the commercial centre for gold for the last 400 years. After the Second World War, the Bank of England was determined to resurrect London as the main commercial centre by making a deal with 7 South African mining companies for importing gold to London for refining and reselling. N.M. Rothschild was the main dealer on those gold deals and on 12th September 1919, 11:00 AM took place the first gold fix with £4.94 per ounce ($20.67). N.M. Rothschild & Sons, Mocatta & Goldsmid, Samuel Montagu & Co., Pixley & Abell and Sharps & Wilkins were the founding members of London Gold Market Fixing Ltd. Until 1968, the fix was in Sterling's, but the dollar price was more important. After the Second World War, it was crucial to maintain a price of $35 per ounce but in 1968, it was not possible anymore and gold was left to float and the fix was changed to dollars. At the same time, an afternoon fix was introduced to serve the customers from New York. (London Gold Market Fixing Ltd, 2006)

London gold fix is carried out twice a day by the 5 members via a dedicated conference call facility. The chairman is ScottiaMocatta and the members are HSBC, Deutche Bank AG London, Societe Generale Corporate & Investment Banking and Barclays Capita. Before every fix, the chairman announces a starting price for the members and the members relay this price to their customers. After this, the customers present themselves as sellers or buyers. Provided there are both seller and buyers, the members are then asked how many bars they would like to trade. If there are either no sellers or buyers, or the amount of bars does not match, a new price is drawn. This procedure is repeated as long as a balance is achieved. Gold fix is achieved when the buyers and sellers are within 25 bars. Transactions made between the parties are principal-to-principal transactions and tie both parties. Gold fix price is also an international benchmark price which is used to value derivatives. (London Gold Market Fixing Ltd, 2006)

2.3.3 Investing in physical gold

Gold has been free from value added tax since 1.1.2000 in Finland. The Council of the European Union approved the Directive concerning the VAT of investment grade gold in 1998. The Directive is aimed at promoting the use of gold as an investment in the Union and to prevent the movement of gold markets out of the EU. Directive is also meant to remove the distortions of competition, caused by different tax treatments amongst the member states. (Finnish Government, 1999)

The directive frees investment grade gold from VAT in the same way as other financial services are free in the current legislation. Transfers of ownership in physical investment grade gold and securities concerning gold are made free of tax. Also importing gold from the member states or outside of the Union is free of value added tax. (Finnish Government, 1999)

Article 26b (A) of the Sixth Directive defines investment grade gold as follows;

i) gold, in the form of a bar or a wafer of weights accepted by the bullion markets, of a purity equal to or greater than 995 thousandths, whether or not represented by securities. Member States may exclude from the scheme small bars or wafers of a weight of 1 g or less;

ii) gold coins which,
   a. are of a purity equal to or greater than 900 thousandths,
   b. are minted after 1800,
   c. are or have been legal tender in the country of origin, and
   d. are normally sold at a price which does not exceed the open market value of the gold contained in the coins by more than 80%.

Banks that sell physical gold are called Bullion Banks. Only nine of these bullion banks are concerned as market making banks. Their businesses include the selling, buying, storing and distribution of gold. The London gold fix has traditionally carried all of these tasks out. Bullion banks also have an important part in creating credit for all the transactions, develop the derivative products and bring credit and liquidity to derivative markets. Bullion banks also trade in their own account, a matter which has brought a lot of rumours about price manipulation. Bullion banks only trade in quantities over 1 000 ounce and are mainly for business-to-business customers. (Cross, 2000)

In Finland there are only two places where one can buy physical gold, TAVEX OY and K.A.Rasmussen. One can also buy gold by a mail order from other countries where the premium is smaller but the expenses might be larger. There are gold coins and small bars available for customers looking to buy only small amounts of gold. These are exempt from VAT. Investing in physical gold is often viewed as protecting oneself for a bad day or a major catastrophe. These investors are often called “gold bugs”. Investing in physical gold is often the first and the easiest choice for people interested in investing in gold.

Gold accounts are a way of owning physical gold. There are two kinds of gold accounts; an Allocated account is an account where the owner has certain marked coins or bars stored in the providers vault and the owner pays an insurance and storage for them. Or an Unallocated account, where the owner only has a certain amount of gold in the providers vault and the owner does not pay any storage or insurance fee. The owner of the Unallocated account bares the risk of bankruptcy by the service provider. Bullion banks and other financial institutions offer gold accounts to customers.

Between owning physical gold and owning gold funds are gold certificates. These are certificates issued by banks, for example in Germany and Switzerland, which entitle the holder for a certain amount of gold in the banks vault. Certificates are a way of owning physical gold without the storage fees, but with a very good liquidity. The holder of the certificate can call the bank at any time to buy more or sell the gold one owns. An Australian certificate program called *Perth Mint* is the only certificate that is backed by the government.

2.3.4 Gold derivatives, funds and stocks

Gold is traded in several stock exchanges around the world. These exchange traded gold or exchange traded funds (GETF) follow the price of gold perfectly, and are 100% backed by gold. *Gold Bullion Securities* was the first GETF launched in March 2003 in the Australian Stock exchange. Its price is the same as one tenth of a gold ounce. Exchange traded gold has become more and more popular in the recent times and many new GETF's have emerged. Exchange traded gold is aimed at investors who are looking for the benefits of physical gold with the ease of purchase and resell. However, in the case of a financial crisis or war, some governments have retained the right to purchase the gold these funds own and therefore lowering the funds value. This makes GETF's have a rare limited upside potential in some countries. Also if the fund goes into bankruptcy, the investor does not have the same rights as an owner of a gold certificate or a gold account for any of the gold the fund possesses and just becomes a normal debtor.

By investing in mining stocks, one can enjoy the benefits of gold investments, but only to a certain degree. If the price of gold goes up, it is quite probable that the stocks of gold mining companies go up and vice versa. However, there are more determinants than the price of gold that determines the stock price of a gold mining company. The volatility of the stocks is also greater than the volatility of gold. Mining companies also use derivatives to a great extend to cover their exposure to changes in the gold price and at the same time they lower their beta against the gold price and increase it against other stocks. Chua et al. (1990) examined the correlation between gold stocks and S&P 500 and noticed that the correlation has increased notably from 1970's to 1980's. They found that the beta of TSE gold index was 0.57 in the 70's and 1.12 in the 80's. This draws a conclusion that gold stocks are not as good diversificators as physical gold.

Commodity futures differ from stocks and physical gold quite much. Commodity futures do not raise capital for the firms and they do not preserve the value like gold. What they do, is they allow the companies to obtain insurance for the value of their future output or input. Investors in commodity futures, e.g. gold futures, receive compensation for bearing the risk of short-term gold price fluctuations. Commodity futures do not represent direct exposure to actual commodities as futures prices represent bets on the expected future spot price. (Gorton and Rouwenhorst, 2006)

Gold derivatives are plentiful and more are invented all the time. Cross (2000) lists the most common ones.

Forwards

- *Fixed forward*
  The most basic forward contract that allows the seller to deliver an agreed volume of gold for an agreed price at a future agreed date.

- *Floating gold rate forward*
  Standard forward contract in which the gold price and interest rates are pre-agreed and locked-in. The gold lease rate is allowed to float and is calculated at maturity based on its performance during the life of the contract.

- *Floating forward*
  Forward contract in which the gold price is pre-agreed but the interest rates and gold lease rates are allowed to float and are calculated at maturity based on their performance during the life of the contract.

- *Spot deferred*
  Forward contract in which the gold price is pre-agreed. Interest rates and gold lease rates are allowed to float. The maturity date is deferrable.

- *Participating forward*
  Forward contract with a purchased call option attached.

- *Advance premium forward*
  A forward contract in which the contango is partly payable in advance.

- *Short-term averaging forward*
  A forward contract locking in an average, not the spot price.

Options

- *Put option*
  A contract that gives the buyer the right but not the obligation to sell gold at a pre-agreed price at an agreed date. There is an obligation on the part of the option writer to take delivery of gold at the agreed price on the agreed date should the option be exercised.

- *Call option*
  A contract that gives the buyer the right but not the obligation to buy gold at a pre-agreed price at an agreed date. There is an obligation on the part of the option writer to deliver gold at the agreed price on the agreed date should the option be exercised.

- *Cap and Collar*
  An option strategy in which the user buys put options and writes call options.

- *Up and in barrier option*
  An option strategy in which the options (either calls or puts) are triggered and come into being if a pre-agreed price level is broken at any stage of the contract life.

- *Down and out barrier option*
  An option strategy (can be either calls or puts) in which the options cease to exist if a pre-agreed price level is broken at any stage of the contract life. A rebate is usually payable if the option is knocked-out, the amount depending on the remaining life of the contract.

- *Convertible forward*
  This is an option strategy that involves the mining industry in buying a vanilla put option and selling a kick-in call option. A feature of this strategy is that the options have the same strike price. A variant of this product is the purchase of the vanilla put with the writing of a knock-out call at a trigger level that is substantially below the option strike price.

Swaps

- *Basic lease rate swap*
  A basic agreement in which gold is lent at a pre-agreed lease rate for a pre-agreed period, usually 3 months. At the end of the period the average lease rate is compared to the contract rate and the differential is paid by the party in debit. The contract is then usually rolled for a further period.

Keynes (1930) and Hicks (1939) made a theory about which side receives the risk premium in a derivative deal. According to them, this premium goes more often to the buyer than the seller. Their “normal backwardation” -theory says; that the producers hedge their output and the speculators make this possible by buying futures and getting a premium from this insurance. They get the premium by demanding the future price to be lower than the future spot price. In gold futures, this is not the case for most of the time. Gold is almost always in contango where the future spot price is lower than the future price. Cross (2000) explains the basic principles of gold futures as follows:

1. Central banks loan the gold to bullion banks and receive a profit which is called the gold lease rate or GOFO (Gold Forward Offered Rate). GOFO is an interest which the central banks loan gold as a swap against US dollar. This makes liquidity to the market and makes derivative market possible.

2. If a producer wants to hedge itself from changes in gold price, buys the bullion bank a future contract from the producer. To finance this transaction, the bullion bank sells the same amount of gold which it lent from the central bank. The money the bullion bank receives from the sale it reinvests into the money markets and receives a normal interest on it. The amount of gold in the market grows as the bullion bank sells its gold to the market and it can affect the gold price if there is not enough demand.

3. When the futures contract ends, the producer delivers the gold to the bullion bank which it has either produced or bought from the market. After this, the bullion bank either returns the gold to the central bank or keeps the gold and makes another future contract.

4. In case of a speculative shot-selling, the case is identical, but the timeframe is longer.

5. The above ground stocks of gold are very large and are generally held in a form that could readily come to market. Further, the willingness on the part of the holders of this metal to participate in the market implies that the cost of borrowing gold remains relatively low compared with money market rates. This is one of the major reasons why the gold forward market is nearly always in contango (forward price higher than spot price, offering a positive interest rate) and only very rarely lapses into backwardation. This positive carry, available to the producer and speculator, means

that the market is implicitly biased towards producer hedging and speculator selling. The transaction will be profitable for the miner or speculator unless the gold price rises at faster rate than the contango.

6. In the last decade, lent gold has increased the amount of gold which is available to the market and therefore it is believed is has affected the gold price.

In the wake of the new millennia, gold derivatives had a very high weight in banks commodity baskets. In 2001 it was as high as 45%, but of all derivatives its share was only 0.3%. In 2006 it only accounted about 7% of all the commodities and 0.12% of all the derivatives (Bank for International Settlements, 2006). It is believed that gold derivatives have been one of the reasons why gold price was so low for a long time. Thru 1990's, the derivative market was growing at fast pace and central banks lent more gold to the market than the market paid it back. An estimate of 400 tonne gold was coming into the markets from the central banks and it played its part in keeping the gold price down. However, this accelerated supply of gold is not the sole reason for the slump of gold in the 1990's. (Neuberger, 2001)

Also many exotic ways of investing exists in the gold markets. Companies like Cantor Index and IG Index for example, offer a way to bet on a price of almost any investments. This betting is called Spread betting. The betting company offers a quote on a price for a certain market. For example $632.12 - $634.09 for gold. If the customer thinks that gold price will rise, he buys gold at $634.09 and bets for example 10$/point on it. If the price of gold goes down and the investor decides to cut losses and sells it at $615.12 - $617.09, he loses the difference of $632.12-$615.12 = $17 multiplied by the bet $10 which is $170. Spread betting is a high risk betting, but the profits from it are tax free and there are no commissions involved.

2.4 Gold as an investment

Hillier, Draper, and Faff (2006) survey the literature on the role of gold and other precious metals in financial markets. They categorize studies into five different approaches. The first approach studies the investment and diversification properties of precious metals when combined with stock market investments in financial portfolios. The second approach concentrates on the role of gold as a potential hedging variable in intertemporal asset-pricing models. The third approach studies the properties of the return distribution and the possibilities for earning excess returns in the gold and silver markets, i.e. the efficiency of these markets. The fourth approach studies the relationships of gold (and silver) to macroeconomic variables and government policy. The final approach concentrates on the particular features and characteristics of gold (and silver) production and market processes. We will look at some of these roles briefly in the following.

By itself, gold is quite a risky asset but its returns are generally independent of those on other assets. This makes gold a good diversifier for portfolios. Chua et al. (1990) and Jaffe (1998) examined the benefits of diversifying investment portfolios with gold stocks and generally observed a diversifying effect for gold. Chua et al. found, that the beta of gold bullion remained virtually indistinguishable from zero thru 1970’s and 1980’s and gold was a meaningful investment for diversification for both long-run and short-run. By using data from 1971 to 1987, Jaffe constructed 4 portfolios mirroring allocations of typical large institutional portfolios with each being different in risk and return. He found that adding 5% gold into all of these portfolios reduced the risk and increased the return of these portfolios and with 10% gold, the benefits increased even more. With more recent data, Hillier et al. (2006) examined the diversification benefits of gold in the US markets and international markets. They used data from period 1976-2004 for S&P 500 and EAFE and found that gold was especially useful diversifier in periods with high volatility and poor performance. When comparing buy-and-hold strategy against switching strategy with gold they found that the former was superior and over the last 25 years, holding 9.5% gold in portfolio was the optimal allocation.

Capie et al. (2004) examined one aspect of the second role of gold, gold as a hedge against US dollar. Using data from 1971 to 2002, they applied a variety of statistical techniques to explore the relationships between gold and the exchange rates of various currencies against the US dollar, with particular attention paid to the hedging properties of gold in episodes of economic or political turmoil. The US dollar gold price was found to move in opposition to the US dollar and the movement was essentially contemporaneous. For each exchange rate considered, a typical weekly movement against the dollar generated a movement in the gold price of just under one dollar.

Gold is also believed to be an effective hedge against inflation. With data from 1976 to 2005, Levin and Wright (2006) found that the US price level and the price of gold moved together in a statistically significant long-run relationship supporting the view that a one percent increase in the general US price level leads to a one percent increase in the price of gold. However, they found that there are short-run deviations from the long-run relationship between the price of gold caused by short-run changes in the US inflation rate, inflation volatility, credit risk, the US dollar trade-weighted exchange rate and the gold lease rate. This is consistent with foundings from Ghosh et al. (2002), Gorton and Rouwenhorst (2006), Kolluri (1981) and Ranson and Wainwright (2005).

3. LITERATURE REVIEW

3.1 Determinants of the price of gold

We will assume that the short-run price of gold is determined by supply and demand. It will fluctuate in response to variables that alter either one. We will first look at the determinants affecting the supply side and then dwell into the demand side.

Gold supply comes from two different sources. Gold is extracted from gold mines (Q^S_{at}) and since early 1980's, the central banks have been willing to lent gold (Q^S_{bt}). Gold producers can therefore supply their customers by leasing gold from central banks, via bullion banks, or extract it from mines. Total supply of gold (Q^S_t) is simply:

$$Q^S_t = Q^S_{at} + Q^S_{bt} \tag{1}$$

According to Levin and Wright (2006), the amount of gold supplied from extraction in any period is positively related to the gold price in an earlier period. This is because there may be a substantial time lag before mines react to a price change. The quantity of gold supplied from extraction is also negatively related to the amount of extracted gold that is diverted to repay central banks for the gold leased in the previous period incremented by a physical interest rate in those cases where the central bank opts for interest to be repaid in gold.

In return for the gold lease rate, central banks forgo the convenience yield. Convenience yield is the benefit of holding gold for a period of time. Central banks adjust their lending to the point where the return they receive from lending is equal to the convenience yield forgone with an added default risk premium. Levin and Wright (2006) state that a fall in the physical interest rate, a rise in default risk or a rise in convenience yield caused by political or financial turmoil would reduce the quantity of gold leased to the industry from central banks in that period. Also, the repayment of gold leased in the previous period impacts on the current period supply. The total supply of gold in any given period fluctuates in response to the current gold price, gold lease rate, convenience yield and default risk premium and also the previous period quantity of leased gold to be repaid at the previous physical interest rate. The previous period quantity of leased gold to be repaid depends on the previous period convenience yield and default risk. Therefore the total supply of gold depends on the current price of gold (P_t) and the current and lagged values of the physical interest rate (*Rg*), the convenience yield (C_y) and the default risk premium (ρ). This combines into equation:

$$Q_t^S = Q^S(P_t, Rg_t, Rg_{t-1}, Cy_{t-1}, Cy_{t-1}, \rho_t, \rho_{t-1}) \qquad (2)$$

The demand of gold (Q^D) consists of two components, the use demand ($Q^D{}_U$) and the asset demand ($Q^D{}_A$). This makes the total demand of gold simply:

$$Q_t^D = Q_{Ut}^D + Q_{At}^D \qquad (3)$$

Like with any other good, the “use” demand for gold is a negative function of gold price. But the asset demand for gold is based on many different factions like the general price level, dollar exchange rate expectations and gold’s beta. The use demand for gold is:

$$Q_{Ut}^D = Q_U^D(P_t) \qquad (4)$$

Gold is believed to have a negative beta, or indistinguishable from zero. This drives the asset demand for gold since gold is an effective diversifier (Chua, Sick and Woodward, 1990). Gold moves against the stock markets, especially in periods where stock markets perform badly and that raise the asset demand for gold. If the beta of gold (*βg*) rises for a period of time, the asset demand will fall during that period, but rises when the beta reverts to its lower value. Therefore the asset demand for gold is negatively related to the current beta and positively related to the lagged values of beta. (Levin and Wright, 2006)

When an investor is holding gold, he is giving up on earning interest on holding another interest bearing asset. This is the cost for holding gold. The price of gold moves inline or against the real interest rate, depending on the causes that move the real interest rate. If the interest rate rises because of fear of rising inflation, the gold moves inline with the real interest rate. The asset demand for gold is:

$$Q_{At}^{D} = Q_{A}^{D}(R_t, \beta g_t, \beta g_{t-1}) \tag{5}$$

When combined, the total demand for gold is:

$$Q_{t}^{D} = Q^{D}(P_t, R_t, \beta g_t, \beta g_{t-1}) \tag{6}$$

The short-run equilibrium occurs when supply equals demand:

$$\underset{+\ +\ \ -\ \ \ \ -\ \ \ \ +\ \ -\ \ +\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ -\ \ -\ \ -\ \ \ +}{Q^{S}(P_t, Rg_t, Rg_{t-1}, Cy_{t-1}, Cy_{t-1}, \rho_t, \rho_{t-1}) = Q^{D}(P_t, R_t, \beta g_t, \beta g_{t-1})} \tag{7}$$

There is an arbitrage relationship between real interest rate and gold lease rate and this solves the impossible task of measuring the real interest rate. In theory, a mine is indifferent between extracting gold now and selling the mined gold now, and leasing gold now, selling the leased gold now, investing the proceeds of the sale in a bond, selling the bond in one year and using the proceeds including interest to pay for extracting the gold plus the physical interest rate. If the cost of extraction rises at the general rate of inflation, the gold lease rate is equal to the real interest rate and the real interest rate needs no longer appear directly in the equation. (Ghosh et al., 2002)

Ghosh et al. (2002) assume linear functional forms for the supply and demand expressions:

$$Q_t^S = aP_t + bRg_t - cRg_{t-1} - dCy_t + eCy_{t-1} - f\rho_t + g\rho_{t-1} \quad (8)$$

$$Q_t^D = -hP_t - iR_t - j\beta g_t + k\beta g_{t-1} \quad (9)$$

They set $R_t = Rg_t$ and solve for P_t:

$$\begin{aligned} P_t = &-\frac{b+i}{a+h}Rg_t + \frac{c}{a+h}Rg_{t-1} + \frac{d}{a+h}Cy_t - \frac{e}{a+h}Cy_{t-1} \\ &+ \frac{f}{a+h}\rho_t - \frac{g}{a+h}\rho_{t-1} - \frac{j}{a+h}\beta g_t + \frac{k}{a+h}\beta g_{t-1} \end{aligned} \quad (10)$$

Now, the derivatives of the price with respect to different variables are:

$$\begin{aligned} &\frac{\delta P_t}{\delta Rg_t} < 0; \frac{\delta P_t}{\delta Rg_{t-1}} > 0; \frac{\delta P_t}{\delta Cy_t} > 0; \frac{\delta P_t}{\delta Cy_{t-1}} < 0; \\ &\frac{\delta P_t}{\delta \rho_t} > 0; \frac{\delta P_t}{\delta \rho_{t-1}} < 0; \frac{\delta P_t}{\delta \beta g_t} < 0; \frac{\delta P_t}{\delta \beta g_{t-1}} > 0 \end{aligned} \quad (11)$$

The long-run price of gold is expected to move with the inflation because the long-run price of gold is tied to the cost of extraction and the extraction costs rise at the general rate of inflation. If the gold producers are profit maximizers, then they are indifferent on the source of gold they supply their customers with. This behaviour ensures that the cost of borrowing gold and extracting gold are equal.

3.2 Empirical results from previous studies

The amount of studies that have attempted to statistically model the price of gold is numerous. These studies can be categorized into three main groups. The first approach, studied by Ariovich (1983), Dooley, Isard and Taylor (1995), Kaufmann and Winters (1989), Sherman (1982, 1983, 1986) and Sjaastad and Scacciallani (1996), models variation in the price of gold in terms of variation in main macroeconomic variables, such as exchange rates, interest rates, world income and political shocks. The second approach represented e.g. by Baker and Van Tassel (1985), Diba and Grossman (1984), Koutsoyiannis (1983) and Pindyck (1993), focus on speculation or the rationality of gold price movements. The third approach represented e.g. by Chappell and Dowd (1997), Ghosh et al. (2004), Gorton and Rouwenhorst (2006 Kolluri (1981), Laurent (1994), Levin and Wright (2006), Mahdavi and Zhou (1997), Moore (1990) and Ranson and Wainwright (2005), examines gold as a hedge against inflation with particular emphasis on short-run and long-run relationships between gold and the general price level. This study falls into the third approach. Each approach is discussed separately in the following sections.

3.2.1 Macroeconomic approach

Dooley, Isard and Taylor (1995) conducted a variety of empirical tests to determine if the price of gold has explanatory power with respect to exchange rates movements. They used multivariate vector autoregression and cointegration modelling techniques with data from 1976 to 1990 to test for the short- and long-run influences of gold prices on exchange rates conditional on other monetary and real macroeconomic variables. They found that gold price movements have explanatory power with respect to exchange rate movements, over and above the effects of movements in monetary fundamentals and other variables that enter standard exchange rate models. This is because they view gold as “an asset without a country" and any type of shock that reduces the attractiveness of holding net claims on A, other things being equal, will normally increase the demands for other assets, both net claims on B and gold, leading to changes in market-clearing prices.

Sjaastad and Scacciallani (1996) investigated the gold and foreign exchange markets for the 1982-1990 period. They found that although the price of gold is usually denominated in US dollars, real appreciations or depreciations of the European currencies have profound effects on the price of gold in all other currencies and the US dollar has only a small influence on the gold price. They also found that the floating exchange rates contributed substantially to the instability of the gold price in the period. Fluctuations in the real exchange rates amongst the major currencies accounted for almost half of the variance in the price of gold.

3.2.2 Speculation or rationality of gold price movements approach

Pindyck (1993) used the futures price data to test the ability of the present value model to explain the prices of four commodities; copper, lumber, heating oil, and gold. He found that the present value model did a poor job in modelling the price of gold. This was partly because gold does not have the same level of convenience yield like many other commodities.

Diba and Grossman (1984) studied the possibility of rational bubbles in the relative price of gold. They studied whether the rational bubbles exist, that is if the time series of the relative price of gold obtained by differencing a finite number of times is nonstationary. They found a close correspondence between the time series of the relative price of gold and the time series properties of real interest rates, which the theory relates to the time series properties of the fundamental component of the relative price of gold. Their evidence is consistent with the conclusion that the relative price of gold corresponds to market fundamentals and the process generating first differences of market fundamentals is stationary, therefore actual price movements do not involve rational bubbles.

3.2.3 Inflation hedge approach

Chappell and Dowd (1997) made a model for the gold standard which modelled technology and preferences explicitly and account was also taken of both the durability of gold and the exhaustibility of gold ore. They examined the steady state and its associated dynamics, and showed how the steady-state price level responds to changes in exogenous factors. Provided they had an interior solution with unminted gold in the steady state, this price level rises with technological progress in gold mining, and falls with increases in real income and the discount rate.

Ghosh et al. (2004) analyzed monthly gold price data from 1976 to 1999 using cointegration regression techniques. Their study provides empirical confirmation that gold can be regarded as a long-run inflation hedge and that the movements in the nominal price of gold are dominated by short-run influences. Their basic model was:

$$P_g = f(P_{usa}, P_w, R_g, Y, \beta_g, er, \theta) \qquad (12)$$

where, P_g is the nominal USA dollar price of gold; P_{usa} is the USA price index; P_w is the world price index; R_g is the gold lease rate; Y is world income; β_g is gold's beta; *er* is the dollar/world exchange rate; and θ are random financial and political shocks that impact on the price of gold. In their final vector error correction mode, ΔlnY and ΔlnP_w were not statistically significant and were left out of the model. They found that $\Delta lnPg$ was statistically significant at lags 1, 2 and 5 which imply that the gold market might not be an efficient market. Other variables that were statistically significant were; ΔlnP_{usa} positive values at 3rd and 6th lags, ΔRg positive at current value and negative value at lags 5 and 6, $\Delta \beta g$ had negative values at the current value and the 5th lag and a positive value at the 6th lag and Δ*lner* was positive at the current value. All these findings were in accordance to the current theory for the price of gold. They also included a long-run error correction mechanism between $lnPg$ and lnP_{usa} which modelled the relationship between these two variables. The error correction mechanism was statistically significant which implies that gold moves together with the US consumer price index and acts as a hedge for inflation. The final model also included thirteen statistically significant period-specific dummies. Nine of these dummies occurred in the later 1970s and early 1980s.

Gorton and Rouwenhorst (2006) studied commodity derivatives and their hedging capabilities in the USA. They used historical data from 1959 to 2004 and found that indices made from spot- and futures prices had beaten inflation. They also noticed that the positive correlation with commodities and inflation was higher in the long-run than in the short-run. They also studied whether commodities could also act as a hedge against unexpected inflation and found a proof for that.

Levin and Wright (2006) developed a theoretical framework based on the simple economics of “supply and demand” that is consistent with the view that gold is an inflation hedge in the long-run, yet at the same time allows the price of gold to fluctuate considerably in the short-run. Their data covered the period from 1976 to 2005. The basic model was:

$$P_g = f(P_{usa}, \pi_{usa}, V(\pi)_{usa}, P_{world}, \pi_{world}, V(\pi)_{world}, Y_{world}, ER, R_g, \beta_g, CRDP, Risk, \theta) \quad (13)$$

where; P_g is the nominal price of gold; P_{usa} is the CPI in the USA; π_{usa} is the rate of change in the US CPI; $V(\pi)_{usa}$ is the US inflation volatility; P_{world} is the IMF “World” price index; π_{world} is the rate of change in the world CPI; $V_{(\pi)world}$ is the world inflation volatility; Y_{world} is world income; ER is the “Nominal Major Currencies Dollar Index”; R_g is the gold lease rate; β_g is

Gold's beta against S&P 500; CRDP is the credit risk default premium; and θ is a set of dummy variables.

Levin and Wright used various cointegration regression techniques to identify key determinants for the price of gold. They found that a one percent increase in the US price level leads to a long-run one percent increase in the price of gold. In the short-run, they found statistically significant positive relationships between changes in the price of gold with changes in US inflation, US inflation volatility and credit risk. And statistically significant negative relationships between changes in the price of gold with changes in the US dollar trade-weighted exchange rate and the gold lease rate. Their error correction mechanism was statistically significant and implied that the price of gold and the US consumer price index move together in the long-run. There also exists a slow reversion towards the long-run relationship following a shock that causes deviation from this. Also 10 ad hoc time dummies were included in the model.

Mahdavi and Zhou (1997) compared the performance of gold and commodity prices as leading indicators of the inflation rate and explored the possibility of improving the inflation rate forecast by specifying error-correction models. They used quarterly price data for gold from the period 1970 to 1994. They found no evidence for a cointegrating relationship between the CPI and the London price of gold over the testing period. However, their study suggests that commodity prices might be a better leading indicator for CPI since they are cointegrated with the CPI. According to Mahdavi and Zhou, the relatively poor out-of-sample forecasts of the price of gold is consistent with the view that short-term movements in the price of gold are too volatile and market specific to forecast relatively gradual and small changes in the general price level in a satisfactory manner.

Moore (1990) used a set of signals based on the leading index of inflation compiled by the Columbia University to examine their relation to the gold price from 1970 to 1988. He found that if an investor followed the signals and bought gold when the up signal flashed and sold on the down signal, the investor would have earned an average annual rate of return of 18 to 20 percent in the period. If he had held gold throughout the period, his rate of return would have been 13.9 percent, while if he had held stocks or bonds throughout, the returns would have been 11.2 percent or 8.7 percent per year.

Ranson and Wainwright (2005) suggest that commodities are the best hedge against inflation and especially gold and other precious metals perform the best. They examined periods of high inflation in the Great Britain and USA, and discovered that the price of gold has gone up 4 years successively before a period of high inflation. The increase in the gold price has been 2 to 3 times as large as the inflation following the increase and it has effectively provided a hedge for inflation. Ranson and Wainwright also studied how an investment in gold could immunize a bond portfolio from inflation. They found that including 18% gold in a bond portfolio immunizes the portfolio from a rise in inflation. However, when inflation rate goes down, the inclusion of gold in bond portfolio could harm the portfolio with its harmful leverage.

4. HYPOTHESES, DATA AND METHODOLOGY

4.1 Hypotheses

Based on the previous empirical research of gold price, we derive several hypotheses that will be tested in this study.

Because gold is believed to have a negative beta, it is used as a diversifier in portfolios. When the beta of gold rise, the diversifying benefits decrease and the asset demand of gold go down and the price goes down.

1. H_0 = Increase in the beta for gold has a negative effect on the price of gold i.e., gold's beta has a negative coefficient in the model for the price of gold.

The asset demand for gold picks up again, when the beta reverts back to its old value.

When an investor is holding gold, he is giving up on return from an alternative interest bearing asset. Therefore, when the current physical interest rate goes up the investor might be tempted to either sell the gold or lend it and invest the money to bonds or money instruments. This increased supply of gold will lower the price of gold.

2. H_0 = Increase in the physical interest rate has a negative effect on the price of gold i.e., physical interest rate has a negative coefficient in the model for the price of gold.

When the physical interest reverts back to a lower value, investors are encourages to invest in gold again.

Increase in the current default risk is likely to increase the asset demand for gold as a hedge against uncertainty and raise the gold price.

3. H_0 = Increase in the default risk has a positive impact on the price of gold i.e., default risk premium has a positive coefficient in the model for the price of gold.

When the uncertainty settles, and the default risk goes down, the hedge demand will decrease and the price will go down as well.

Many studies (Chappell and Dowd, 1997; Ghosh et al., 2004; Gorton and Rouwenhorst, 2006; Kolluri, 1981; Laurent, 1994; Levin and Wright, 2006; Mahdavi and Zhou, 1997; Moore, 1990 and Ranson and Wainwright, 2005) have found that gold can act as a viable hedge against inflation.

4. H_0 = Gold moves with the general price level and can be regarded as a long-run hedge against inflation i.e., there is a cointegration vector between the price of gold and either one of the consumer price indexes.

When gold acts as a hedge against inflation, high inflation or high inflation volatility accelerates the demand for gold and rises the gold price

5. H_0 = High inflation or high inflation volatility has a positive effect on the price of gold i.e., high inflation or inflation volatility has a positive coefficient in the model for the price of gold.

4.2 Data

The data used in the modelling are monthly observations from the first day of the month covering the period from December 1972 to August 2006. In some cases, the world consumer price index and Moody's bond yields, the series are published on the 15th of each month. Also the gold forward offered rate is only available from July 1989 onwards and therefore the physical interest rate is only included in a sub-period model from July 1989 to August 2006. Each variable is discussed more thoroughly below.

The price of gold (*Pg*) is the monthly afternoon (p.m.) closing price of the London gold fix. The gold price is provided by The World Gold Council. The US CPI (P_{USA}) and the world CPI (P_{WORLD}) are from Thomson Datastream database.

The world and US inflation rates (π_{USA} and π_{WORLD}) are calculated from the CPI data using equation (14).

$$\pi_t = \frac{CPI_t}{CPI_{t-12}} - 1 \tag{14}$$

Inflation volatilities [$V(\pi_{USA})$ and $V(\pi_{WORLD})$] are calculated as coefficient of variation for inflation over twelve months by using equation (15) where ρ_π is the variation of inflation in the previous twelve months and $\bar{\pi}$ is the mean of inflation in the previous twelve months. The variation of inflation is the square root of the standard deviation for inflation.

$$V(\pi) = \frac{\rho_\pi}{\bar{\pi}} \tag{15}$$

The beta of gold (*βg*) is calculated by regressing the percentage monthly gold return on the percentage monthly S&P 500 index return using a sample period of 36 months. S&P 500 index is from Thomson Datastream database.

The gold lease rate (*Rg*) is used to test the second hypotheses. Gold leasing officially started in 1982, but The London Bullion Market Association started to publish the mean GOFO (Gold Forward Offered Rates) not until July 1989. Prior to that, there were no composite rates on the market. Therefore, the gold lease rate is only included in the modelling in a sub-period model from July 1989 to August 2006. The gold lease rate is calculated by subtracting the three-month GOFO from the three-month LIBOR rate. The three-month gold forward rate and three-month LIBOR dollar interest rate are from Thomson Datastream database.

Credit default risk premium (*CDRP*) is included in the model to test the third hypothesis. It is calculated as the yield gap between “Moody’s Seasoned Aaa Corporate Bond Yield” and “Moody’s Seasoned Baa Corporate Bond Yield” expressed as proportion equation (16) (Levin & Wright, 2006). Average yields on Moody’s long term corporate Aaa and Baa bonds were obtained from Thomson Datastream database.

$$CDRP_t = \frac{Baa_t - Aaa_t}{Aaa_t} \tag{16}$$

Finally, the US-world exchange rate index (*er*) is included to control for movements in the price of gold denominated in US dollars caused by exchange rate movements that are not associated with changes in the relative price levels between the USA and the rest of the world. The index used is Trade Weighted Exchange Index: Major Currencies and is from Board of Governors of the Federal Reserve System. It is a weighted average of the foreign exchange value of the U.S. dollar against a subset of the broad index currencies that circulate widely outside the country of issue.

4.3 Econometric model

We will be using cointegration regression techniques, developed by Johansen (1988, 1991), to identify the key determinants for the price of gold. The Johansen procedure has been successfully used in previous studies on gold by Ghosh et al. (2004) and Levin and Wright (2006).

In this subjection, we will introduce the reader with vector autoregressive (VAR) model, cointegration and the vector error correction (VEC) model.

4.3.1 Vector autoregressive model

The vector autoregressive model is commonly used for forecasting systems of interrelated time series. *A priori*, it treats every variable as endogenous and as a function of the lagged values of all the endogenous variables in the system. This makes VAR a very flexible model that is not bound on prior beliefs based on uncertain theoretical considerations. It can include a constant and linear terms or seasonal dummies, and independent Gaussian errors. (Johansen, 1995)

The mathematical representation of VAR is:

$$y_t = A_1 y_{t-1} + \cdots + A_p y_{t-p} + Bx_t + \in_t \quad (17)$$

where y_t is a k vector of endogenous variables, x_t is a d vector of exogenous variables, A_1, …, A_p and B are matrices of coefficients to be estimated, and $\in_t$ is a vector of innovations that may be contemporaneously correlated but are uncorrelated with their own lagged values and uncorrelated with all of the right-hand side variables. Since only lagged values of the endogenous variables appear on the right-hand side of the equations, simultaneity is not an issue and OLS yields consistent estimates. (Enders, 1995)

When working with a VAR model, one needs to consider whether to include a deterministic trend into the equation or not. Investing time into a proper trend specification may prevent a substantial power loss in a case where the wrong specification is used. Usually a visual inspection of the plots of the time series under study can reveal a trend or the underlying theory can help with the specification. There are also statistical procedures that can help in deciding on the deterministic components. Five different deterministic trend cases are considered by Johansen (1995):

1. The level data y_t have no deterministic trends and the cointegrating equations do not have intercepts:

$$H_2(r): \mathbf{\Pi} y_{t-1} + Bx_t = \alpha\beta' y_{t-1} \quad (18)$$

2. The level data y_t have no deterministic trends and the cointegrating equations have intercepts:

$$H_1^*(r): \mathbf{\Pi} y_{t-1} + Bx_t = \alpha(\beta' y_{t-1} + \rho_0) \quad (19)$$

3. The level data y_t have deterministic trends but the cointegrating equations have only intercepts:

$$H_1(r): \mathbf{\Pi} y_{t-1} + Bx_t = \alpha(\beta' y_{t-1} + \rho_0) + \alpha_\perp \gamma_0 \quad (20)$$

4. The level data y_t and the cointegrating equations have linear trends:

$$H^*(r): \mathbf{\Pi} y_{t-1} + Bx_t = \alpha(\beta' y_{t-1} + \rho_0 + \rho_1 t)\alpha_\perp \gamma_0 \quad (21)$$

5. The level data y_t have quadratic trends and the cointegrating equations have linear trends:

$$H(r): \mathbf{\Pi} y_{t-1} + Bx_t = \alpha(\beta' y_{t-1} + \rho_0 + \rho_1 t) + \alpha_\perp (\gamma_0 + \gamma_1 t) \quad (22)$$

The terms associated with $\alpha_{\perp}$ are the deterministic terms “outside” the cointegrating relations. When a deterministic term appears both inside and outside the cointegrating relation, the decomposition is not uniquely identified.

There has been a debate whether the variables in VAR need to be stationary or not. Sims (1980), Doan (1992) and others, recommend against differencing even if the variables contain a unit root. Their argument is that the goal of VAR analysis is to determine the interrelationships among the variables, not the parameter estimates. They argue that differencing throws away information concerning the comovements in the data, such as cointegrating relationships. However, if the variables are nonstationary, a vector error correction (VEC) model is preferred. For this reason, a normal VAR is often called the “levels” VAR. Also it is argued that the data need not to be trended as a trending variable will be approximated in a VAR by a unit root plus drift. (Enders, 1995)

Empirically, another important part of VAR specification is the lag length selection, since the number of parameters grows very fast with the lag length and the information criteria strike a compromise between lag length and number of parameters by minimizing a linear combination of the residual sum of squares and the number of parameters (Enders 1995). The optimal lag length can be determined by some of the many information criterion procedures. Akaike info criterion (AIC), Schwarz criterion (SC) and Hannan-Quinn criterion (HQ) are the commonly accepted criterions. The AIC criterion asymptotically overestimates the order with positive probability, whereas the last two criteria estimate the order consistently under quite general conditions (Lütkepohl & Krätzig, 2004).

4.3.2 Cointegration

To implement the VEC model successfully, we must make sure that some of the time series are cointegrated. That is, if there exists a linear combination of two nonstationary series, integrated of order one $I(1)$, that is stationary, these series are called cointegrated series. Cointegration measure, introduced by Granger (1981) and Engle and Granger (1987), answers the question of a long-term common stochastic trend between nonstationary time series. If nonstationary series *x* and *y* are both integrated of same order and there is a linear combination of them that is stationary, they are called cointegrated series and the vector of this relationship is called the cointegrating vector. Accordingly, cointegrated series share a common stochastic trend. It follows that these two series will not drift apart too much, meaning that even if they deviate from each other in the short-term, they will revert to the long-run equilibrium.

Two basic methodologies are available for testing cointegration; Engle-Granger and Johansen methodologies. Engle-Granger (1987), building upon the representation theorem of Granger (1983), introduce a two-step procedure where first an ordinary least squares (OLS) regression is estimated on the integrated of order one data and then residuals of the regression are checked for stationarity. Granger representation theorem suggests that in a bivariate system of $I(1)$ series *x* and *y*, if lagged *x* improves the estimation of *y* , then *x* is said to Granger cause *y*. “Granger causality” suggests a lead-lag relationship between time series and there may be “Granger causality” between asset prices without the presence of a cointegrating vector. However, cointegration implies a Granger casual flow between the integrated assets.

The Johansen (1991) methodology is a maximum likelihood approach for testing cointegration in multivariate autoregressive models. Its objective is to find the linear combination which is most stationary, relying on the relationship between the rank of a matrix and its eigenvalues. The

Johansen methodology provides two statistics to determine the number of cointegrating vectors: Trace and Maximum Eigenvalue statistics. Johansen and Juselius (1990) advise “Trace” statistic which tests the null hypothesis of r cointegrating relations against the alternative of n cointegrating relations, where n is the number of variables in the system for $r = 0,1,2 \ldots n\text{-}1$. The Maximum Eigenvalue on the other hand tests the null hypothesis of r cointegrating relations against the alternative of r+1 cointegrating relations for $r = 0,1,2 \ldots n\text{-}1$. The critical values are presented by Johansen and Julieus (1990) and Osterwald-Lenum (1992).

4.3.3 Vector error correction mechanism

Vector error correction mechanism is a restricted version of VAR designed to be used with nonstationary series that are known to be cointegrated. The error correction terms were first used by Sargan (1964), Hendry and Anderson (1977) and Davidson et al. (1978) as a way of capturing adjustments in a dependent variable which dependent not on the level of some explanatory variable, but on the extent to which an explanatory variable deviated from an equilibrium relationship with the dependent variable.

When VEC mechanism is used, one will need to consider the cointegration rank r in addition to the lag order. Cointegration rank can be determined by sequential testing procedures based on likelihood ratio (LR)-type of tests. In this study, the Johansen (1991) methodology is used to determine the cointegration rank.

A rather general VECM form, which includes deterministic trends and exogenous variables, can be obtained from the levels VAR by subtracting y_{t-1} from both sides and rearranging terms:

$$\Delta y_t = \prod y_{t-1} + \mathbf{\Gamma}_1 \Delta y_{t-1} + \cdots + \mathbf{\Gamma}_{p-1} \Delta y_{t-p+1} + CD_t + Bz_t + u_t \qquad (23)$$

here $\prod$ = -(I_K - A_1 -…- A_p) and $\mathbf{\Gamma}_l$ = -(A_{i+1} +…+ A_p) for l = 1,…, p-1, z_t s are unmodelled stochastic variables, D_t contains all regressors associated with deterministic trends, and C and B are parameter matrices. $\prod y_{t-1}$ contains the cointegrating relations. For example, if we have three variables with 2 cointegration relations (r = 2), we have:

$$\prod y_{t-1} = \alpha\beta' y_{t-1} = \begin{bmatrix} \alpha_{11} \alpha_{21} \\ \alpha_{21} \alpha_{22} \\ \alpha_{31} \alpha_{32} \end{bmatrix} \begin{bmatrix} \beta_{11} \beta_{21}\ \beta_{31} \\ \beta_{12} \beta_{22}\ \beta_{32} \end{bmatrix} \begin{bmatrix} y_{1,t-1} \\ y_{2,t-1} \\ y_{3,t-1} \end{bmatrix} \qquad (24)$$

where we can derive the error correction term from the last two matrices

$$ec_{1,t-1} = \beta_{11} y_{1,t-1} + \beta_{21} y_{2,t-1} + \beta_{31} y_{3,t-1} \qquad (25)$$

and

$$ec_{2,t-1} = \beta_{12} y_{1,t-1} + \beta_{22} y_{2,t-1} + \beta_{32} y_{3,t-1} \qquad (26)$$

the matrix α is sometimes called the loading matrix, it contains the weights attached to the cointegrating relations, and β cointegration matrix. The matrices α and β are not unique.

In this study, a meaningful error correction mechanism (ECM) for the long-run relationship is of the form:

$$ecm_{t-1} = \alpha(\beta_{11} \ln Pg_{t-1} - \beta_{21} \ln P_{USAt-1} - \beta_{31} \ln P_{WORLDt-1}) \qquad (25)$$

where $lnPg$, lnP_{USA} and $lnP_{WORL})$ are cointegrated variables and α is the speed of adjustment parameters, or a loading matrix, and β_{xx} are the cointegration coefficiencies, or matrices. The adjustment parameter is expected to lie between 0 and -1. This particular ECM implies the existence of the following cointegration vector:

$$\beta_{11} \ln Pg_t = m + \beta_{21} \ln P_{USAt} - \beta_{31} \ln P_{WORLDt} + \omega_t \tag{26}$$

where ω, is a white noise process and *m* represents possible non-stochastic elements of the vector.

If restrictions are available for the cointegration space from economic theory, it is useful to take them into account in estimating the ECM parameters. Restrictions can be imposed on both the coefficients and the adjusting parameters. If the appropriate measure of the general price level is a linear combination of lnP_{USA} and lnP_{WORLD} we would expect to find that restrictions β_{11} = -1 and $\beta_{21} + \beta_{31}$ = -1 hold.

4.3.4 Modelling process

Our modelling process can be divided into three parts. First we do the long-run modelling, and then proceed to the short-run modelling and finally we do the model checking. In the long-run analysis, we form an ECM for the long-run relationship between the price of gold and the two general price levels. In the short-run analysis, we form a VEC model from the parameters and include the ECM constructed in the long-run part. In the model checking, we test whether the given VEC model provides an adequate representation of the data generation process underlying the time series set of interest. We use EViews 5.1 for all these steps.

We start our analysis by forming an ECM for the long-run relationship between the price of gold and the general price levels. This is done by first constructing an unrestricted VAR from *Pg*, P_{USA} and P_{WORLD} and determining the lag length by AIC, SC and HQ criterions. From the unrestricted VAR we also test whether to include a deterministic trend or not.

We then proceed with the Johansen procedure to test for the cointegration rank. When the cointegration rank is established, we will form a VEC model and impose restrictions on the equation (25) and test if they hold. If the restrictions hold, we check the model residuals for normality and serial correlation. If the residuals show large outliers we will include a set of empirically determined *ad-hoc* time dummy variables to overcome this problem and start the process from the start with the dummy variables. When the residuals are normally distributed and show no serial correlation, we have found the cointegration relationships.

When the long-run relationship has been found, we estimate the following short-run model for the entire period:

$$\begin{aligned}\Delta \ln Pg_t &= \alpha + aA(L)\Delta \ln Pg_{t-1} + bB(L)\Delta P_{USAt} + cC(L)\Delta \pi_{USAt} \\ &+ dD(L)\Delta \pi_{WORLDt} + eE(L)\Delta V(\pi)_{USAt} + fF(L)\Delta V(\pi)_{WORLDt} \\ &+ gG(L)\Delta \beta g_t + hH(L)\Delta CDRP_t + iI(L)\Delta \ln(er)_t + \sum_k \theta_k t_k \\ &+ \gamma ecm_{t-1} + u_t\end{aligned} \tag{27}$$

and the following model for the sub-period from July 1989 to August 2006:

$$\begin{aligned}\Delta \ln Pg_t &= \alpha + aA(L)\Delta \ln Pg_{t-1} + bB(L)\Delta P_{USAt} + cC(L)\Delta \pi_{USAt} \\ &+ dD(L)\Delta \pi_{WORLDt} + eE(L)\Delta V(\pi)_{USAt} + fF(L)\Delta V(\pi)_{WORLDt} \\ &+ gG(L)\Delta \beta g_t + hH(L)\Delta CDRP_t + iI(L)\Delta \ln(er)_t + jJ(L)\Delta Rg_t \\ &+ \sum_k \theta_k t_k + \gamma ecm_{t-1} + u_t\end{aligned} \tag{28}$$

where α is a constant; *A(L),B(L), …, J(L)* are finite order lag polynomials; *a, b, …, j* are vectors of the parameters associated with these lag polynomials; θ_k is an empirically determined set of *k* period specific (t_k) dummy variables; *u* is a random error term; ecm_{t-1} is the error correction mechanism constructed from the results of the cointegration tests. We also include lnP_{USA} to the short-run model to be able to use the VEC model and calculate the ecm_{t-1} in the model. The error correction term used is a unitary cointegration vector:

$$ecm_{t-1} = \ln Pg_{t-1} - \ln P_{USAt-1} \quad (29)$$

We first test an unrestricted VAR to determine the number of lags we include in the model by AIC, SC and HQ criterions. Then we estimate the models (27) and (28) without including any period specific dummies and carry out model checking tests to evaluate the suitability of the model. These tests include the Jargue - Bera normality test and autocorrelation LM test.

After the first undummied model is estimated, we plot the residuals to see if there are any clear outliers that could be dummied out. Then we include a set of time-specific dummies to dummy out the effect of these outliers. These dummy variables are convergent with the dummies used by Levin and Wright (2006). When these dummies are included, we test the model again with the model checking tests specified above.

5. EMPIRICAL RESULTS

5.1 Descriptive statistics and trends in explanatory variables

In this section, we present and discuss the descriptive statistics related to the variables used in this study. The summary of descriptive statistics is shown in Table 1.

Table 1. Descriptive statistics for the period January 1973 to August 8.2006. Table shows descriptive statistics for all variables used in the long-run and short-run models. In the actual models, the number of observations is slightly less because of the use of lags. In the table ln represents natural logarithm and Δ represents 1st differences. *Pg* is the price of gold, P_{USA} is the US price index, P_{WORLD} is the world price index, π_{USA} is the US inflation, π_{WORLD} is the world inflation, $V(\pi)_{USA}$ is the US inflation volatility, $V(\pi)_{WORLD}$ is the world inflation volatility, *er* is the exchange rate index, *Rg* is the gold lease rate, *βg* is the beta of gold and *CRDP* is the credit risk default premium.

Variable	Mean	Max.	Min.	Std. Dev.	Skewness	Kurtosis	Obs.
$\ln Pg$	5.744	6.502	4.173	0.424	-1.204	4.185	405
$\Delta \ln Pg$	0.006	0.253	-0.253	0.059	0.562	7.173	404
$\ln P_{USA}$	4.741	5.317	3.754	0.428	-0.695	2.368	405
$\Delta \ln P_{USA}$	0.004	0.018	-0.007	0.003	0.746	4.368	404
$\ln P_{WORLD}$	3.192	4.825	0.904	1.280	-0.234	1.599	405
$\Delta \ln P_{WORLD}$	0.010	0.040	-0.002	0.006	0.988	5.697	404
π_{USA}	0.048	0.146	0.011	0.031	1.327	3.910	405
$\Delta \pi_{USA}$	$-3.90e^{-05}$	0.017	-0.018	0.004	-0.101	5.198	404
π_{WORLD}	0.126	0.321	0.029	0.066	0.401	2.950	405
$\Delta \pi_{WORLD}$	$-7.94e^{-05}$	0.035	-0.029	0.007	0.724	9.020	404
$V(\pi)_{USA}$	0.146	0.464	0.027	0.090	1.236	4.304	405
$\Delta V(\pi)_{USA}$	0.000	0.133	-0.139	0.024	-0.335	10.530	404
$V(\pi)_{WORLD}$	0.099	0.397	0.009	0.069	1.182	4.974	405
$\Delta V(\pi)_{WORLD}$	$-7.71e^{-05}$	0.047	-0.043	0.014	-0.072	4.259	404
$\ln(er)$	4.588	4.969	4.383	0.120	0.752	3.374	405
$\Delta \ln(er)$	-0.001	0.051	-0.054	0.017	-0.238	3.144	404
Rg (%)	1.014	6.903	0.058	0.866	2.140	12.820	206
ΔRg (%)	-0.010	3.864	-3.989	0.541	-0.143	29.279	205
βg	-0.024	1.244	-0.981	0.396	1.194	4.364	405
$\Delta \beta g$	0.002	0.452	-0.484	0.069	-0.283	-0.283	404
$CRDP$	0.125	0.245	0.071	0.038	0.908	3.001	405
$\Delta CRDP$	$9.94e^{-05}$	0.070	-0.059	0.013	0.573	7.686	404

We can see from the table that skewness and kurtosis values indicate that none of the variables in levels data are normally distributed. Formal Jarque-Bera tests confirm this observation. In first differences, $\Delta ln(er)$ is the only variable that can be regarded as normally distributed.

We also examine the bivariate relationships between the nominal price of gold and each explanatory. However, it is important to note that this kind of analysis may reveal spurious trends and correlations that do not have any statistical value.

From Figures 3 to 12, we can examine the levels data plotted against the gold price. We can see that Pg, P_{USA} and P_{WORLD} have upward sloping trends while the other variables seem to have none.

Figures 3 and 4 plot the price of gold against the US price index and the world price index. While both indexes trend upwards, the world price index starts to get steeper in the early 1990's. Gold seems to act as better long-run hedge against US inflation as it is to world inflation. However, there are significant short-run deviations.

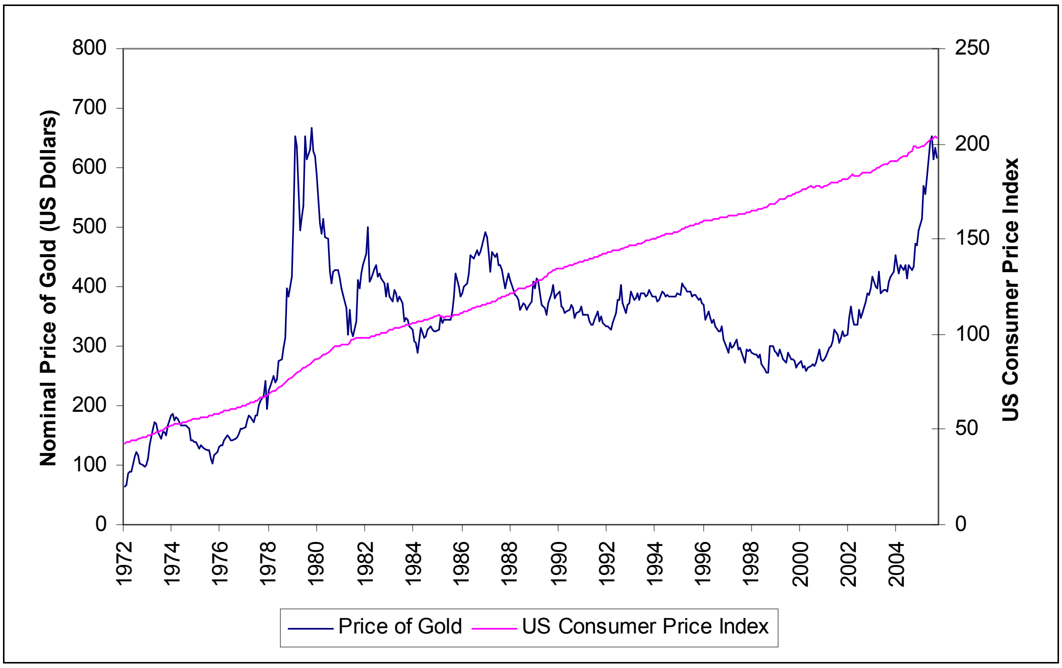

Figure 3. Price of gold and the US consumer price index from 1972 to 2006.

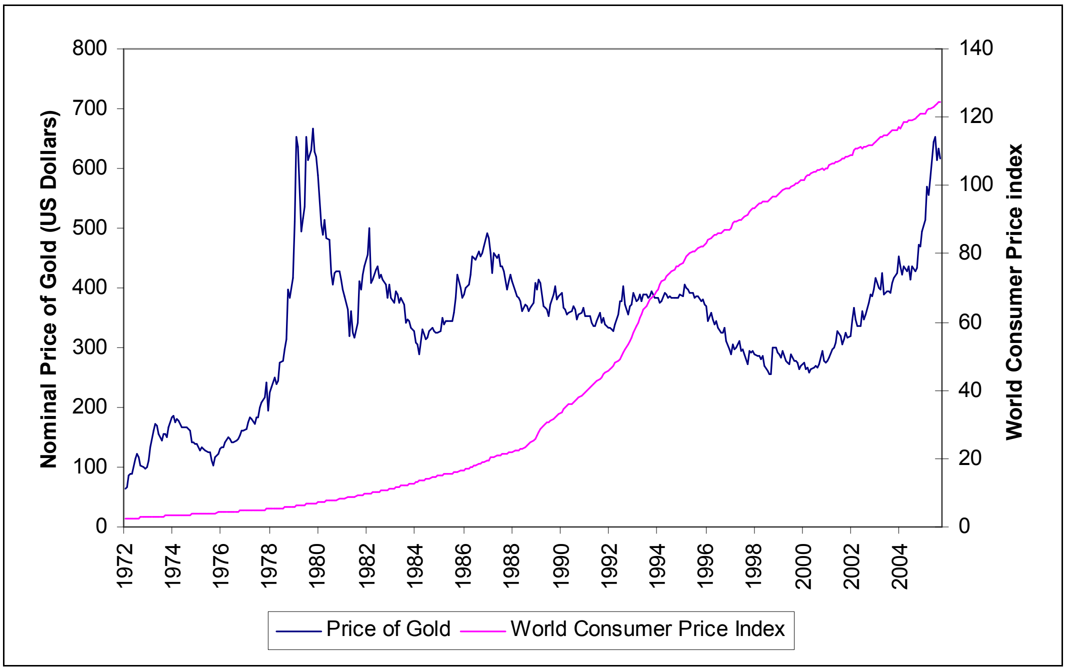

Figure 4. Price of gold and the world consumer price index from 1972 to 2006.

In Figures 5 and 6, the price of gold is plotted against US inflation and world inflation. Theory suggests that the price of gold is higher during periods of high inflation. This seems to hold true only in the late 70's and early 80's for US inflation and world inflation, but not on other times.

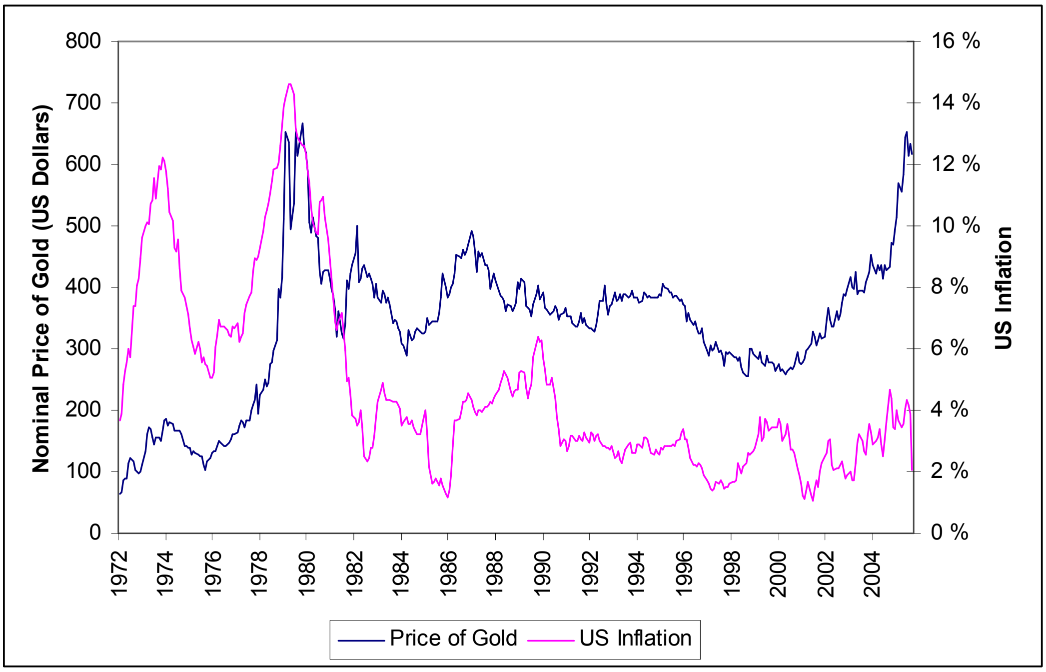

Figure 5. Price of gold and US inflation from 1972 to 2006.

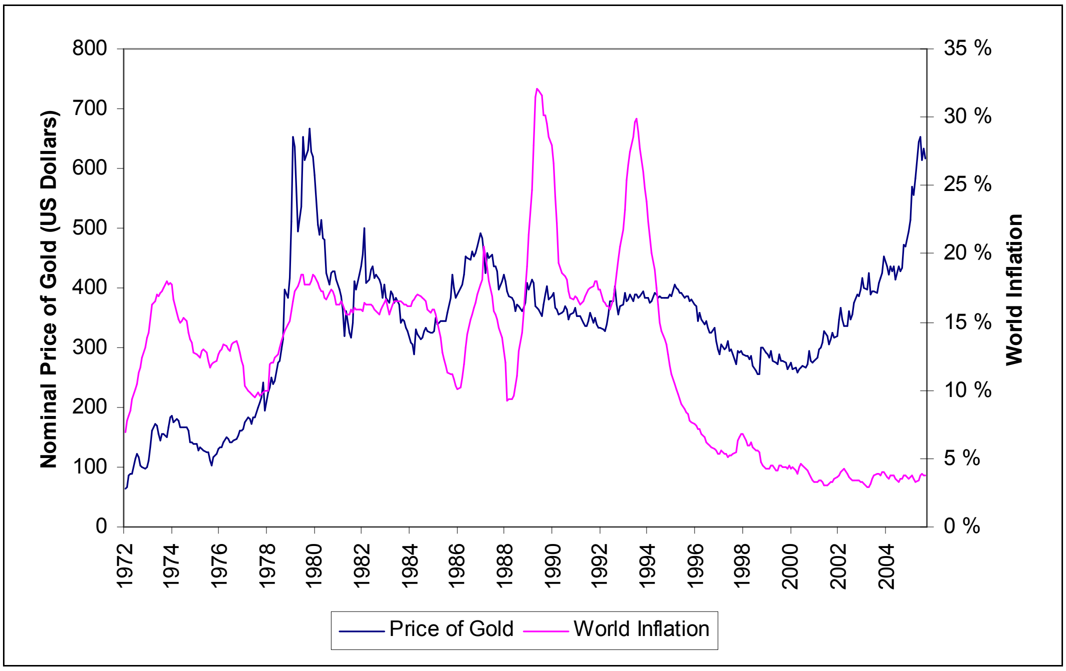

Figure 6. Price of gold and world inflation from 1972 to 2006.

From Figures 7 and 8, we cannot notice any clear relationship between US inflation volatility or world inflation volatility and the price of gold.

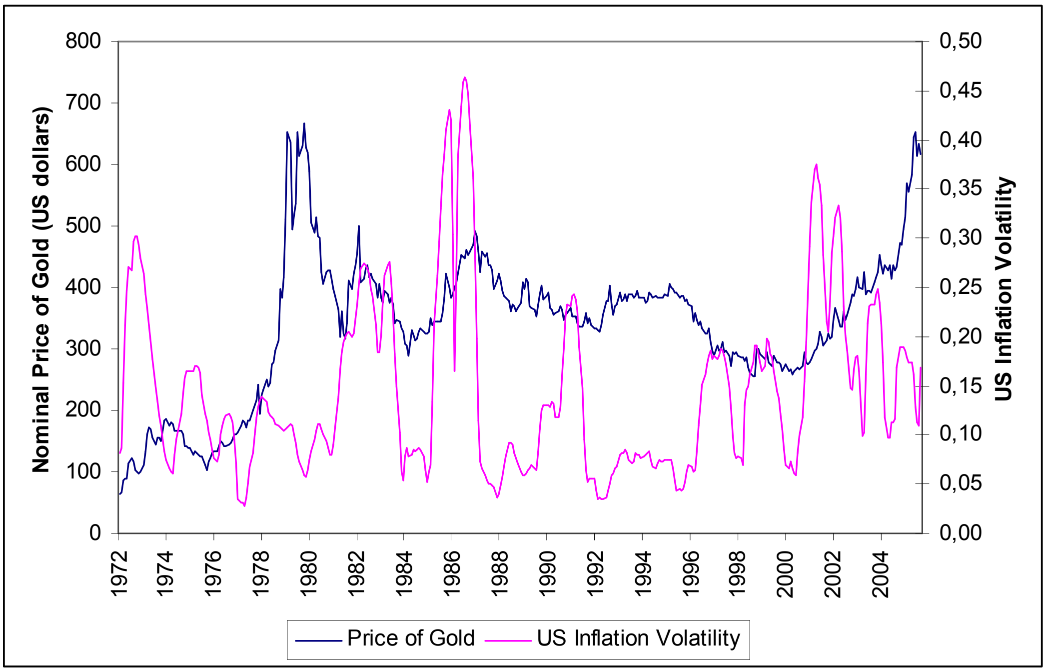

Figure 7. Price of gold and US inflation volatility from 1972 to 2006.

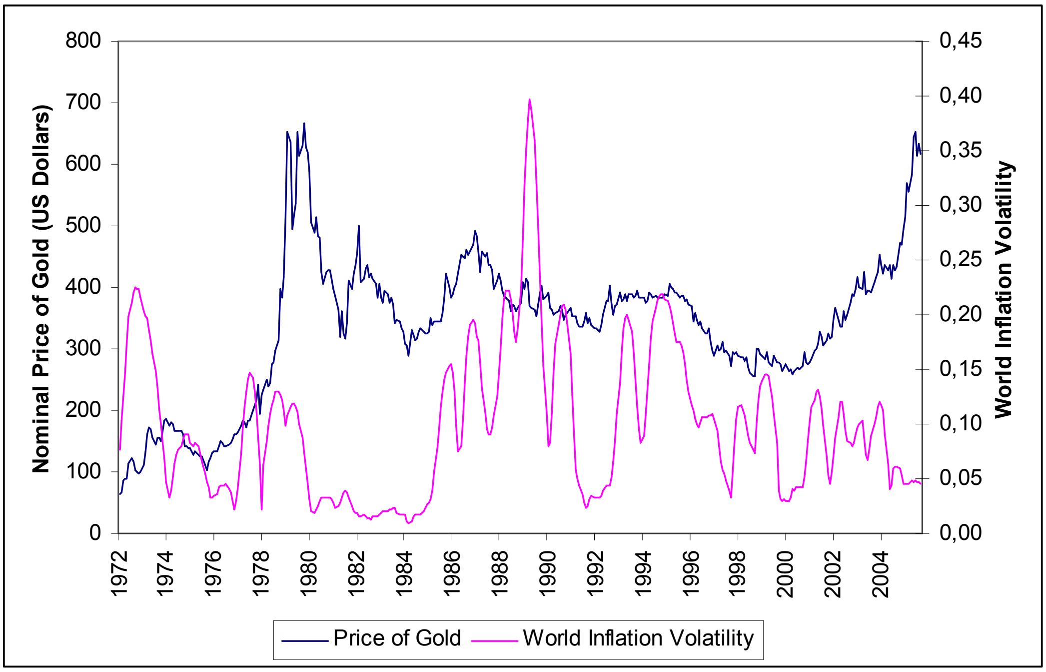

Figure 8. Price of gold and world inflation volatility from 1972 to 2006.

Figure 9 plots the price of gold and default premium together. Theory suggests that the price of gold should be lower during periods of low credit risk, when the central banks are willing to lend more gold. There is some evidence of this in the 90's where the price of gold was very stable.

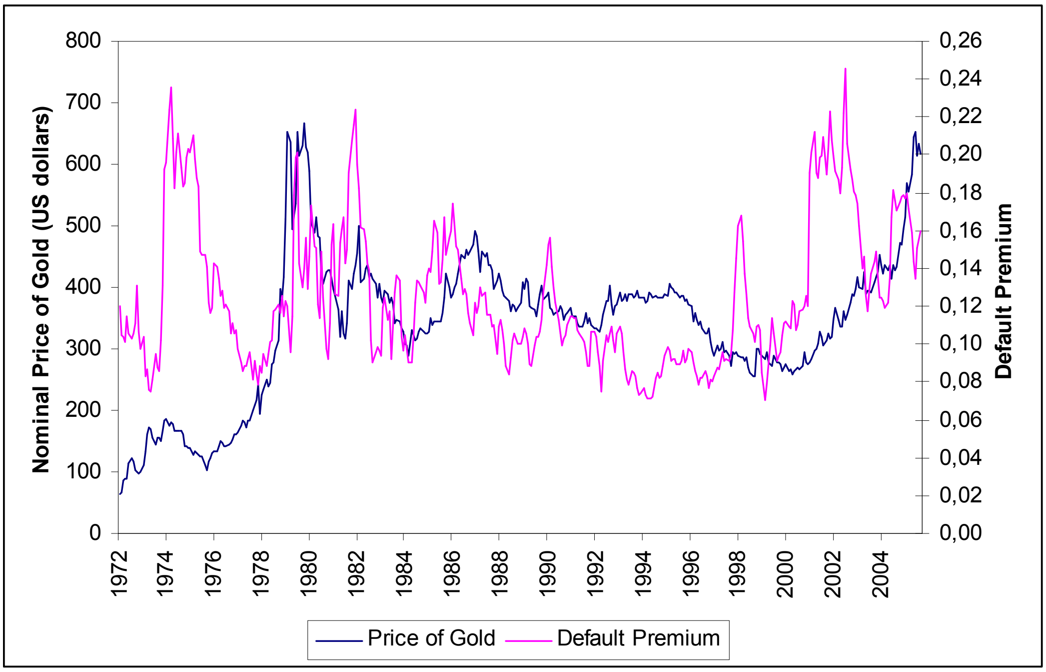

Figure 9. Price of gold and default premium from 1972 to 2006.

From Figure 10 we can notice a clear negative relationship between the price of gold and the US dollar-world exchange rate. This is as expected. When the price of dollar rises, gold becomes more expensive for investors outside the USA. This lowers the demand for gold and this in turn, lowers the price of gold.

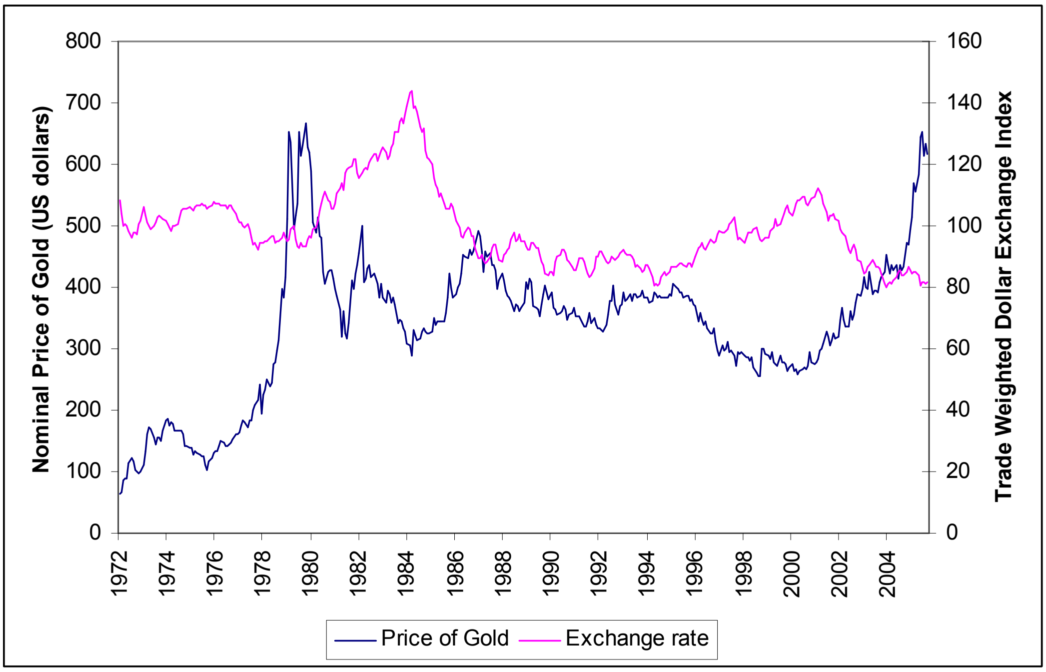

Figure 10. Price of gold and the US-world exchange rate index from 1972 to 2006.

From Figure 11, we can examine the effect of gold's beta to the price of gold. Theoretically there should be a negative relationship between the two. This negative relationship is slightly noticeable on time periods from 1974 to 1978 and from 1986 to 2000.

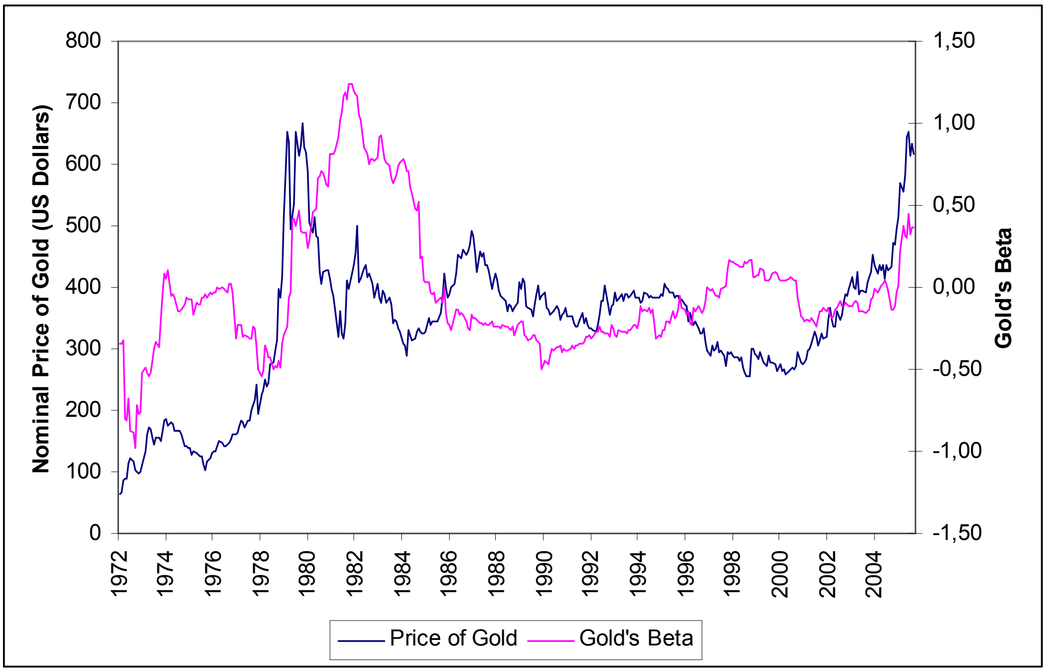

Figure 11. Price of gold and gold's beta against S&P 500 from 1972 to 2006.

Figure 12 shows quite clearly how the gold lease rate affects the gold price. When the lease rate is high, 1989 to 2001, central banks are tempted to lease the gold and thus increase the supply and keep the price steady. From 2001 onwards, the gold lease rate has been low and the supply of gold from leasing is lower, thus increasing the price of gold.

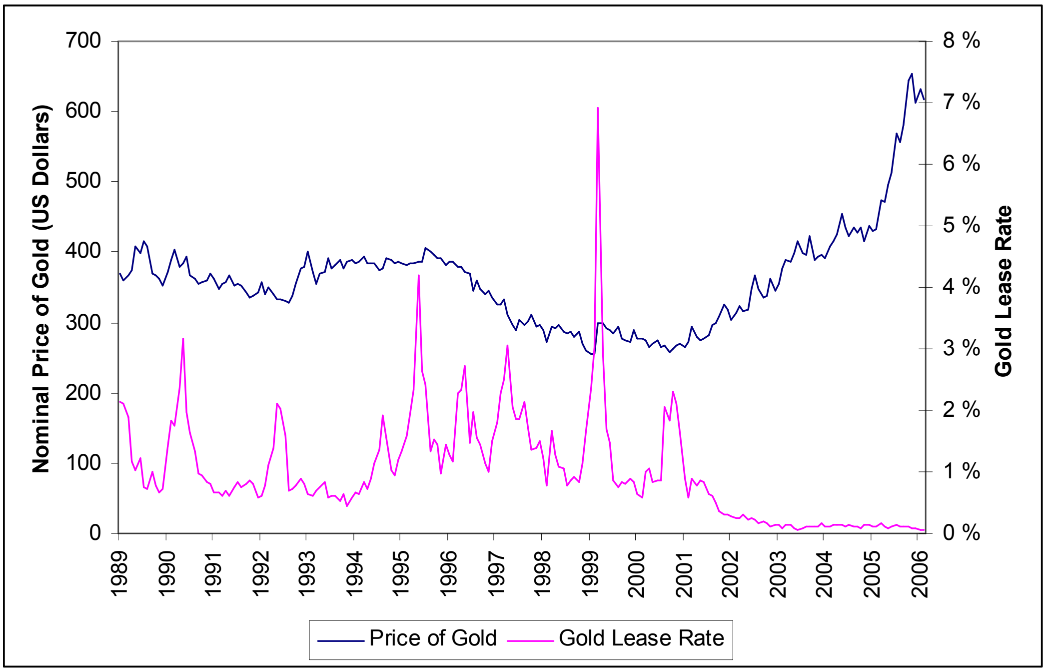

Figure 12. Price of gold and gold lease rate from 1972 to 2006.

While this bivariate analysis might give a good insight to the trends in the variables, it is of utmost important to study these variables together in a multivariate analysis holding other factors constant.

We also examined the pair wise correlations between variables used in the regressions. This is reported in Table 2. The panel shows us that only $\ln P_{USA}$ and $\ln P_{WORLD}$ have a very high correlation and therefore $\ln P_{WORLD}$ is dropped from the equations.

Table 2. Correlation matrix. Table shows pair wise correlations between variables used in the regressions. The data used is levels data. We can see that only $\ln P_{USA}$ and $\ln P_{WORLD}$ have a very high correlation and $\ln P_{WORLD}$ is therefore dropped from the equations.

	lnPg	*βg*	*CRDP*	*lnER*	$\ln P_{USA}$	$\ln P_{WORLD}$	π_{USA}	$V(\pi)_{USA}$	π_{WORLD}	$V(\pi)_{WORLD}$
lnPg	1.000									
βg	0.323	1.000								
CRDP	0.032	0.259	1.000							
ln(er)	-0.268	0.601	0.161	1.000						
$\ln P_{USA}$	0.669	0.062	-0.023	-0.380	1.000					
$\ln P_{WORLD}$	0.523	-0.069	-0.054	-0.453	**0.975**	1.000				
π_{USA}	-0.195	0.001	0.050	0.090	-0.710	-0.734	1.000			
$V(\pi)_{USA}$	0.003	0.031	0.335	0.187	0.035	0.019	-0.215	1.000		
π_{WORLD}	0.104	0.015	-0.228	0.054	-0.343	-0.417	0.333	-0.258	1.000	
$V(\pi)_{WORLD}$	-0.002	-0.573	-0.291	-0.452	0.026	0.080	-0.007	0.025	0.248	1.000

5.2 Unit Root tests

The Augmented Dickey-Fuller (ADF) test was used to test the null hypothesis of a unit root for the entire data set. The results from the test are reported in table 3. Augmented Dickey-Fuller test was performed without an intercept and time trend, with an intercept and with an intercept and a time trend.

Table 3. Unit Root Tests. This table shows the results from the Augmented Dickey-Fuller tests for the variables used in the models. The optimal lag length for the ADF is selected with the Schwartz Info Criterion and maximum lag is set to 17.

	Levels			1st differences		
	None	Intercept	Intercept and tend	None	Intercept	Intercept and trend
lnPg	1.649	-3.450***	-3.229*	-18.719***	-18.852***	-18.903***
lnP_{USA}	1.099	-5.314***	-2.657	-1.808*	-2.330*	-7.200***
lnP_{WORLD}	1.067	-1.845	0.592	-1.578	-2.695*	-3.340*
π_{USA}	-1.597	-1.845	-2.676	-6.643***	-6.662***	-6.656***
π_{WORLD}	-0.977	-1.037	-1.757	-7.731***	-7.745***	-7.771***
$V(\pi)_{USA}$	-2.481**	-5.135***	-5.177***			
$V(\pi)_{WORLD}$	-1.837*	-2.900**	-4.088***	-6.698***	-6.709***	-6.704***
ln(er)	-0.505	-1.681	-2.140	-14.481***	-14.473***	-14.470***
Rg	-3.184***	-4.722***	-5.144***			
βg	-1.729*	-1.697	-1.693	-19.515***	-19.503***	-19.479***
CRDP	-0.845	-3.778***	-3.777**	-15.233***	-15.216***	-15.198***

***, ** and * indicate statistical significance at the 1%, 5% and 10% levels respectively.

Results from the ADF test show that $V(\pi)_{USA}$, $V(\pi)_{WORLD}$ and *Rg* are *I(0)* variables, which is not surprising. In addition, *lnPg*, π_{USA}, π_{WORLD}, *ln(er), βg* and *CRDP* are *I(1)* variables, as expected, i.e. they are stationary upon first differencing. However, lnP_{USA} and lnP_{WORLD} are both *I(2)* variables, they need to be differenced twice to be stationary. This could be problematic since, in a strict sense, it excludes the possibility of a cointegrating relationship between them and *lnPg*. However, one must remember that unit root tests have low power and are adversely affected by outliers. Also, lnP_{USA} can be regarded as *I(1)* variable at the 10% significance level without a trend or intercept and with an intercept and at 1% level with an intercept and a time trend. Therefore we include lnP_{USA} as an *I(1)* variable along the other variables. Models that mix variables in different levels of differencing often fail residual tests badly; also the liberal approach adopted here is widespread in the applied cointegration literature (Levin and Wright 2006). We also opted to drop lnP_{WORLD} from the models because it is an *I(2)* variable and furthermore, lnP_{USA} and lnP_{WORLD} have a high correlation between them (0.975), which also suggests that it might be legitimate to drop it.

5.2 Long-run relationships

The theoretical arguments presented in Section 3 suggest that if there is a long-run relationship between the nominal price of gold and the general price level, the variables should be cointegrated. Our unit root tests and formal correlation tests suggests that we should drop lnP_{WORLD} from the equations (25) and (26). That leaves us with a two variable VAR, *lnPg* and lnP_{USA}.

We started out with the Johansen procedure with an unrestricted VAR. Table 4 presents the lag length choice criteria and normality test results from the two variable VAR involving *lnPg* and lnP_{USA}.

Table 4. Choice criteria and normality tests. This table shows the choice criteria for selecting the order of the VAR and normality tests. Schwarz criterion (SC) and Hannan-Quinn criterion (HQ) both indicate a lag length of two while Akaike information criterion (AIC) found no meaningful lag length. Normality tests failed.

		Choice criteria	
Order	AIC	SC	HQ
1	-12.032	-11.971	-12.008
2	-12.314	-12.213*	-12.274*
3	-12.295	-12.213	-12.129
Normality tests		Jarque-Bera	Prob.
lnPg		217.180	<0.001
lnP_{USA}		236.833	<0.001
Joint		454.014	<0.001

* indicates the optimal lag length.

From our initial VAR, we find that both SC and HQ criterions suggest a lag length of 2. However, normality tests show that the residuals are not normally distributed, which is a requirement for the Johansen's methodology. A plot of the residuals from the *lnPg* shows a number of large outliers that might be responsible for failing the normality tests. We included a number of dummies as exogenous variables to overcome this problem. Table 5 presents the lag length choice criteria and normality test results from the two variable VAR involving $lnPg$ and lnP_{USA} with dummy variables included.

Table 5. Choice criteria and normality tests. This table shows the choice criteria for selecting the order of the VAR and normality tests. Schwarz criterion (SC), Hannan-Quinn criterion (HQ) and Akaike information criterion (AIC) indicate a lag length of two. The model also passed the normality tests.

Choice criteria			
Order	AIC	SC	HQ
1	-12.640	-12.084	-12.420
2	-12.896*	-12.301*	-12.661*
3	NA	NA	NA

Normality tests	Jarque-Bera	Prob.
$lnPg$	0.043	0.979
lnP_{USA}	4.539	0.103
Joint	4.583	0.333

* indicates the optimal lag length. Order 3 and onward could not be tested because a dummy variable intervening the 3rd lag.

After including a set of dummy variables, all the information criterion tests suggest a lag length of 2. Also the residuals show normal distribution. We therefore continue the cointegration test with these dummies.

As we needed to include a numerous dummy variables, EViews 5.1 refused to do the cointegration estimates. Instead of EViews 5.1, we used JMulTi to estimate the number of cointegration vectors. JMulTi gives us two test statistics, Trace test statistic and Saikkonen & Lütkepohl test statistic. Table 6 presents the tests for cointegration in the order 2 VAR, with and without the dummies, since the inclusion of dummies invalidates the standard critical values for the Johansen trace test. Saikkonen & Lütkepohl (S&L) tests critical values are indifferent with or without dummies.

Table 6. Cointegration tests for *lnPg* and *lnP*$_{USA}$. This table shows the trace- and Saikkonen Lütkepohl (S&L) cointegration tests for VAR with a constant and a time trend in the levels data but only intercepts in the cointegration equations. We tested two hypotheses, if the first one was rejected; we did not do the second one and accepted that the equation had no cointegrating vectors. If we did reject the first, but not the second, we accepted that the equation had one cointegrating vector.

Trace test without dummies for *lnPg* and lnP_{USA}			
Null Hypothesis	Alternative hypothesis	Statistic	95% Critical value
r=0	r=1	85.14	25.73
r<=1	r=2	11.62*	12.45
Trace test with dummies for *lnPg* and lnP_{USA}			
Null Hypothesis	Alternative hypothesis	Statistic	95% Critical value
r=0	r=1	99.94	25.73
r<=1	r=2	11.26*	12.45
S&L test with dummies for *lnPg* and lnP_{USA}			
Null Hypothesis	Alternative hypothesis	Statistic	95% Critical value
r=0	r=1	53.25	15.76
r<=1	r=2	1.55*	6.79

* indicate statistical significance at the 5% level.

Both test statistics show that the null hypothesis of at most 0 cointegrating vectors is rejected and the null hypothesis of at most 1 cointegrating vector is not. The just identified cointegrating vector for the dummied VECM with a constant and a time trend in the levels data but only intercepts in the cointegration equations is:

$$\underset{\text{(imposed)}}{\ln Pg} = c + \underset{(0.23378)}{2.0654} \ln P_{USA} \tag{30}$$

standard errors in parenthesis, EViews do not give standard error for constant.

Because we have imposed a restriction of *lnPg* = -1 for the cointegration vector, it enables us to obtain a standard error for the parameter on lnP_{USA} and generate a confidence interval for the long-run parameter attached to it. A long-run parameter of unity is clearly within this confidence interval. We also find that the *ecm* for the $\Delta lnPg$ equation is -0.009 (0.004) and 0.0013 (0.000) for the ΔlnP_{USA} equation, standard errors in parenthesis.

A parameter of 1 on lnP_{USA} theoretically implies long-run price homogeneity. Imposing this restrictions on the *ecm* term along with $lnPg$ = -1, we find that the *ecm* for the $\Delta lnPg$ equation is 0.0215 (0.007) and -0.0015 (0.000) for the ΔlnP_{USA} equation, standard errors in parenthesis.

Our main findings from the long-run analysis are that there is a long term relationship between the price of gold and the US price level, that is, a one percent increase in the general US price level leads to a one percent increase in the price of gold. There also exists a slow reversion towards the long-term relationship after a shock that causes a deviation from this long-term relationship. The error correction term 0.0215 implies that each month's error is about 2 per cent smaller than the previous month. This is inline with findings from Levin and Wright (2006); they found that the error correction term was -0.019. These findings gives us ground to accept the 4th hypothesis that gold moves with the general price level and can be regarded as a long-run hedge against inflation.

5.3 Short-run relationships

In order to explore the short-run dynamics of the model, we estimated equations (27) and (28). We started with an initial unrestricted VAR to see how many lags would be included. Table 7 presents the lag choice criteria tests for both models.

Table 7. Choice criteria. This table shows the choice criteria for selecting the order of the VAR and normality tests. Schwarz criterion (SC) and Hannan-Quinn criterion (HQ) both indicate a lag length of two while Akaike information criterion (AIC) found no meaningful lag length for the full model. Schwarz criterion (SC) was the only criterion to find a lag length for the sub period model.

Panel A: Full period model

Order	AIC	SC	HQ
1	-53.306	-52.396	-52.946
2	-56.070	-54.340*	-55.384*
3	-56.133	-53.585	-55.123

Panel B: Sub-period model from September 1989 to August 2006

Order	AIC	SC	HQ
1	-54.922	-53.069	-54.172
2	-57.707	-54.170*	-56.275
3	-57.671	-54.449	-55.557

* indicates the optimal lag length.

We find that both SC and HQ criterions favour a lag length of 2 for the full period model. For the partial model, only SC criteria finds a suitable lag length, both AIC and HQ criterions are unable to find a proper lag length. We also ran residual diagnostic tests including normality and serial correlation tests. Jarque-Bera test shows us that the residuals of *lnPg* are not normally distributed for the full model and serial correlation tests show no serial correlation at lags 3 and onwards. For the partial model, we found that it passes the Jarque-Bera test of normality and it shows no serial correlation at lags 2 and onwards. We also estimated VEC models and found that the full model did not perform very well in explaining Δ*lnPg* with an adjusted R^2 of 9.7%; the sub-period model performed the same with an adjusted R^2 of 10.0%.

Looking at the residuals of *lnPG*, we find a large number of outliers that might be the cause of failing the normality test for the full model. We decided to include a number of time-specific dummy variables in the models to dummy out the effect of these outliers. Including these dummies in the VEC models the full model also passes the Jarque-Bera test of normality and serial correlation tests show no serial correlation at lags 3 and onwards. The adjusted R^2 becomes 51.4%, a good fit for a model in first differences. For the sub-period model, adjusted R^2 only picks up to 19.5% after the inclusion of dummies. From Table 8a we can see the results of the full model.

Table 8a. Results. This table shows the results from the full model. March 1973 to August 2006.

Variable	Coefficiency	Standard error	t-stat	Predicted sign
$\Delta lnPg_{-1}$	-0.010	(0.041)	[-2.429]**	
$\Delta lnPg_{-2}$	0.007	(0.041)	[0.172]	
ΔlnP_{USA-1}	1.586	(1.366)	[1.161]	
$\Delta lnNP_{USA-2}$	0.558	(1.337)	[0.417]	
$\Delta \pi_{USA\ -1}$	1.866	(0.933)	[2.000]**	+
$\Delta \pi_{USA\ -2}$	0.157	(0.894)	[0.175]	+
$\Delta \pi_{WORLD\ -1}$	0.395	(0.472)	[0.836]	+
$\Delta \pi_{WORLD\ -2}$	0.081	(0.461)	[0.174]	+
$\Delta V(\pi)_{USA\ -1}$	0.132	(0.119)	[1.110]	+
$\Delta V(\pi)_{USA\ -2}$	-0.032	(0.122)	[-0.261]	+
$\Delta V(\pi)_{WORLD\ -1}$	0.524	(0.263)	[1.985]**	+
$\Delta V(\pi)_{WORLD\ -2}$	-0.433	(0.257)	[-1.684]*	+
$\Delta ln(er)_{-1}$	-0.730	(0.142)	[-5.135]***	-
$\Delta ln(er)_{-2}$	0.182	(0.147)	[1.233]	-
$\Delta \beta g_{-1}$	0.011	(0.033)	[0.324]	-
$\Delta \beta g_{-2}$	-0.060	(0.034)	[-1.768]*	-
$\Delta CRDP_{-1}$	-0.003	(0.166)	[-0.017]	+
$\Delta CRDP_{-2}$	0.384	(0.168)	[2.286]**	+
ecm_{t-1}	-0.017	(0.008)	[-2.069]**	-
constant	-0.005	(0.005)	[-1.091]	
D1973_8	-0.175	(0.045)	[-3.856] ***	
D1974_1	0.174	(0.044)	[3.985] ***	
D1974_2	0.178	(0.044)	[4.001] ***	
D1978_11	-0.191	(0.042)	[-4.482] ***	
D1979_9	0.230	(0.042)	[5.464] ***	
D1979_12	0.174	(0.043)	[4.079] ***	
D1980_1	0.250	(0.043)	[5.772] ***	
D1980_3	-0.253	(0.044)	[-5.725] ***	
D1980_6	0.197	(0.046)	[4.236] ***	
D1981_1	-0.140	(0.043)	[-3.248] ***	
D1982_4	0.122	(0.043)	[2.876] ***	
D1982_5	-0.127	(0.043)	[-2.960] ***	
D1982_8	0.222	(0.043)	[5.216] ***	
D1983_1	0.097	(0.043)	[2.270] **	
D1983_2	-0.157	(0.043)	[-3.672] ***	
D1985_3	0.117	(0.042)	[2.787] ***	
D1986_9	0.102	(0.042)	[2.419] **	
D1990_3	-0.105	(0.044)	[-2.402] **	
D1999_9	0.131	(0.042)	[3.121] ***	

***, ** and * indicate statistical significance at the 1%, 5% and 10% levels respectively

Table 8b presents the simple OLS statistics for the Δ*lnPg* equation as well as statistics for the entire VEC model including normality test results.

Table 7b. Model specification statistics. This table shows the model specification statistics for the full model. It shows the R^2 and adjusted R^2 statistics, the standard error of the equation, two information criterion tests and a normality test.

Test	Statistic
R-squared	0.531
Adjusted R-squared	0.482
Standard error of equation	0.041
Akaike information criterion	-55.538
Schwarz criterion	-51.959
Jarque-Bera df.(2)	3.515

The model specification tests show us that we have good fit for the model and the model passes normality test. The information criterion test statistics were the lowest in this final model. The Jarque-Bera test statistics show us that we have a normally distributed model.

Overall, the parameters estimates are consistent with the main hypotheses proposed in previous chapter. Lagged values of *ΔlnPg* are statistically significant at the first lag. This finding is not surprising since Levin and Wright (2006) and Ghosh et al. (2004) have found similar results, although with a positive sign. We also tested the model with more lags to see if other lagged values of *ΔlnPg* were statistically significant and found that the sixth lag was also significant, also with a negative sign. These findings points to the possibility that the gold market might not be an efficient market.

Lagged values of $\Delta\pi_{USA}$ are statistically significant at the first lag with a large positive sing. This positive effect on the price of gold can be explained by short-run increases in the demand for gold that occurs when investors buy gold to hedge for the inflation.

Lagged values of $\Delta V(\pi)_{WORLD}$ are statistically significant at lags one and two. The first lag is positive and the second negative. This could be explained by linking the world inflation volatility to international “instability”. An increase in uncertainty leads to an increase in the demand for gold to hedge for that uncertainty, but these uncertainties do not last long and when the situation calms down, the demand drops to the level it was before the time of uncertainty, which could explain the positive sing on the first lag.

The first lag of *Δln(e)r* is statistically significant with a large negative sign. This is consistent with the theory. Demand for gold by non-USA investors’ falls in response to a rise in *ln(er)* since this change in the exchange rate would raise the price of gold expressed in non-dollar currencies. When the dollar strengthens, the price of gold rises for investors outside the dollar area even though the dollar price remains intact. Therefore a rise in *ln(er)* causes a reduction in the demand for gold by investors outside the dollar area. Since the parameter is so much closer to minus one than to zero (-0.73), we could say that the majority of the gold market resides outside the dollar area.

The second lag of *Δβg* is statistically significant with a negative sign. Theory suggests that the diversification benefit gold holds, is associated with its negative beta. This seems to be true, although the rise in gold price occurs after 2 months of the decline in beta.

The second lag of *ΔCRDP* is also statistically significant with a positive sign. This is also inline with the theory that an increase in the current default risk is likely to increase the asset demand for gold as a hedge against uncertainty and raise the gold price.

Finally, the *ecm* parameter of -0.016, is statistically significant. Therefore the error correction mechanism is well behaved since it lies between 0 and -1. This finding confirms that *lnPg* and lnP_{USA} are indeed cointegrated and move together in the long-run. The magnitude of this coefficient is however rather small compared to the other statistically significant components of our model.

It is worth noting that ΔlnP_{USA}, $\Delta\pi_{WORLD}$ and $\Delta V(\pi)_{USA}$ were not statistically significant in our model. Exclusion of ΔlnP_{USA} can be explained by the error correction mechanism explaining most of the variation coming from ΔlnP_{USA}.

We also included 19 statistically significant period-specific dummies. It is difficult to precisely pinpoint the events behinds these sudden jumps and falls in the nominal price of gold. Many of them tend to cluster around the late 1970's and early 1980's and might capture the high uncertainty that followed the OPEC oil price shock of 1979. Also the 1973 and 1974 dummies could include the uncertainty caused by Saudi oil prices which rose over fivefold from 1973 to 1974. Also the 1982 dummies can be associated by raising oil prices which were caused by the turbulence in the Middle East. The September 1999 dummy includes the effect of the first Central Bank Gold Agreement.

These results suggest that the nominal price of gold is dominated by short-run influences and the long-run relationship has less impact at any given time. Also the inclusion of numerous dummies to make the model pass the tests is problematic. One hypothesis is that the political risk and uncertainty dramatically affect the short-run price of gold and the dummy variables pick up these effects.

From table 9a we can see the results of our sub-period model, where we included *Rg* to test the hypothesis about the physical interest rate and whether a high gold lease rate depresses the gold price.

Table 9a. Results. Results from the partial model. October 1989 to August 2006.

Variable	Coefficiency	Standard error	t-stat	Predicted sign
$\Delta lnPg_{-1}$	-0.173	(0.071)	[-2.406]**	
$\Delta lnPg_{-2}$	-0.043	(0.072)	[-0.596]	
ΔlnP_{USA-1}	3.499	(2.058)	[1.700]*	
$\Delta lnNP_{USA-2}$	-1.301	(2.078)	[-0.625]	
$\Delta \pi_{USA\ -1}$	0.143	(1.433)	[0.100]	+
$\Delta \pi_{USA\ -2}$	-1.052	(1.425)	[-0.738]	+
$\Delta \pi_{WORLD\ -1}$	0.543	(0.620)	[0.875]	+
$\Delta \pi_{WORLD\ -2}$	-0.432	(0.595)	[-0.725]	+
$\Delta V(\pi)_{USA\ -1}$	-0.066	(0.174)	[-0.382]	+
$\Delta V(\pi)_{USA\ -2}$	0.129	(0.175)	[0.741]	+
$\Delta V(\pi)_{WORLD\ -1}$	0.415	(0.290)	[1.430]	+
$\Delta V(\pi)_{WORLD\ -2}$	-0.250	(0.295)	[-0.847]	+
$\Delta ln(er)_{-1}$	-0.516	(0.168)	[-3.060]***	-
$\Delta ln(er)_{-2}$	0.014	(0.171)	[0.085]	-
$\Delta \beta g_{-1}$	0.004	(0.060)	[0.073]	-
$\Delta \beta g_{-2}$	0.125	(0.059)	[2.112]**	-
$\Delta CRDP_{-1}$	-0.302	(0.242)	[-1.248]	+
$\Delta CRDP_{-2}$	0.402	(0.237)	[1.695]*	+
ΔRg_{-1}	0.002	(0.004)	[0.590]	-
ΔRg_{-2}	$-2.92e^{-05}$	(0.004)	[-0.006]	-
ecm_{t-1}	-0.007	(0.013)	[-0.497]	-
constant	-0.003	(0.006)	[-0.444]	
D1990_3	-0.105	(0.037)	[-2.813]***	
D1999_9	0.141	(0.035)	[3.992]***	

***, ** and * indicate statistical significance at the 1%, 5% and 10% levels respectively

Table 9b presents the simple OLS statistics for the Δ*lnPg* equation as well as statistics for the entire VEC model including normality test results.

Table 8b. Model specification statistics. This table shows the model specification statistics for the full model. It shows the R^2 and adjusted R^2 statistics, the standard error of the equation, two information criterion tests and a normality test.

Test	Statistic
R-squared	0.286
Adjusted R-squared	0.194
Standard error of equation	0.033
Akaike information criterion	-57.487
Schwarz criterion	-53.407
Jarque-Bera df.(2)	5.680

The model specification tests show us that we do not have as good fit for the model as we had for the full model, but the model passes normality test just fine.

The sub-period model tried to capture the movements of the price of gold from a time where the price of gold was at first stagnant and then sky rocketed to a threefold. It did not perform as well as expected as only 3 variables were statistically significant at 95% confidence level and *ΔRg* was not one of them.

Now that we have completed analysing our results, we can turn to our hypotheses and see whether they are rejected or not. Our first hypothesis states that an increase in the beta for gold has a negative effect on the price of gold. We fail to reject the hypothesis, although the effect of the beta is from the second lag and it is significant only at the 90% confidence interval.

Our second hypothesis states that an increase in the current physical interest rate has a negative effect on the price of gold. We reject the hypothesis and state that the physical interest rate has no effect on the price of gold according to our partial model. However, a levels test would have been a more appropriate test to determine whether the gold lease rate has an effect on the price of gold. We can see from the figure 12 that when the gold lease rate was high, the price of gold remained stagnant and as the lease rate fell to near 0 and stayed there for the last 5 years, the price of gold rallied up.

Our third hypothesis states that an increase in the current default risk has a positive impact on the price of gold. Our tests clearly show that we fail to reject this hypothesis as the CRDP is statistically significant and with a positive sign. The impact is not immediate as only the second lag was significant.

Our fourth hypothesis states that gold moves with the general price level and can be regarded as a long-run hedge against inflation. We fail to reject this hypothesis based on both our long-run and short-run tests. Our error correction mechanism states that after a shock, that causes a deviation from the long-term relationship of gold and the general price level of the USA, there exists a slow reversion towards the long-term relationship. The reversion is about 1.6% per month.

Our last hypothesis states that a high inflation or high inflation volatility has a positive effect on the price of gold. We fail to reject this hypothesis also on the grounds of $\Delta\pi_{USA}$ and $\Delta V(\pi)_{WORLD}$ being statistically significant at the first lag with a positive sign.

6. CONCLUSIONS

This study investigates the different methods investors can invest in gold and the short-run and long-run price determinants for the price of gold. In the first part of the study, we investigated the possible investment methods available for investors who are interested in investing in gold. The second part concentrated on the short-run and long-run price determinants.

We found that there are numerous different methods one can invest in gold. Each of them has their benefits and downsides. Those that are after a long-run protection against uncertainty or inflation are encouraged to invest in physical gold, either in the form of coins or bars or a certificate or gold account. These forms of investments do not have the ease or liquidity of exchange traded gold, but they have the “security” of a physical asset. And those after the risk/reward ratio gold offers are often tempted by the exchange traded gold or derivatives.

Overall, gold is traded in every major exchange around the world in many forms and is readily available to any investor that has access to these exchanges. Also, physical gold can be bought from everywhere either in physical form or in certificates.

We laid out five hypotheses in this study about how the determinants of the price of gold would behave. Only one hypothesis was rejected. The determinants we tested were chosen because of their popularity in the applied literature and for their availability. They were US and world consumer price indexes, US and world inflation, US and world inflation volatilities, US-world exchange rate index, beta of gold, credit risk default premium, and gold lease rate. Cointegration regression techniques were used to identify what the key determinants of the price of gold are. This method can be used to isolate the factors that are correlated with movements of a variable in both the short-run and the long-run.

Our results are consistent with the previous studies, the long-run relationship between the price of gold and the US price level being the most notable finding. Using an error correction mechanism to examine the long-run relationship between the two and, we found that the price of gold and the US price level to move together. There also exists a slow reversion towards the long-run relationship after a shock that causes a deviation from this relationship.

We estimated two short-run models to analyse the determinants for the price of gold, a sub-period model and a full period model. The sub-period model performed poorly compared to the full model. We found evidence that the US Inflation, world inflation volatility, US-world exchange rate index, beta of gold and credit risk default premium were all statistically significant variables. World consumer price index was left out of the model because it was a $I(2)$ variable and correlated with the US price index too much. The world inflation, US inflation volatility and gold lease rate were not statistically significant variables. However, gold lease rate was only included in the sub-period model and a formal bivariate analysis show that when the gold lease rate has been low, the price of gold has rallied up, and when the lease rate was high, the price of gold was in stalemate.

We also included 19 statistically significant time-specific dummy variables in our model. Inclusion of these dummies was based on statistical criteria. These dummies are likely to capture the high global uncertainty and oil crises in these periods.

Overall, our results give further evidence that gold can be regarded as a long-run hedge against the inflation and that the price of gold moves inline with the general price level. However, the movements in the nominal price of gold are dominated by short-run influences and that the long-run relationship has less impact at any given time

There exist two major issues that need further research. The first concerns gold as a long-run inflation hedge for other countries than USA. If an investor is domiciled in a country whose currencies depreciate against the US dollar more than required to compensate for the difference between the country's and US inflation rate, can holding gold be profitable. But it remains to be seen whether gold acts as a hedge against inflation or not for other countries.

The second concerns the number of dummies needed to include in the model. Two previous studies by Ghosh et al. (2004) and Levin and Wright (2006) had the same problem, even though we had a longer time frame and more variables, we needed more dummies than they. We believe that gold responds strongly to political turmoil and we need better proxies for the political risk. However, there will still exist one-time shocks, like the central bank agreement, even though we could include the political risk better in our model.

Finally, we turn to policy implications of this analysis for potential investors in gold. An investor, that holds assets in US dollars, should profit, if they are holding gold in their portfolio if the expected depreciation of US dollar realises. The dollar depreciation would lower the price of gold to investors outside the USA and raise the demand for gold and raise the US dollar price of gold. Also, dollar depreciation would be likely to raise inflation in the USA and gold would act as an inflation hedge in this period. For a non US investor, dollar depreciation would lower the price of gold for them and make it more attractive. However, we think that it is not possible to predict the price of gold with an adequate accuracy by using any statistical methods. There are simply too many *ad-hoc* determinants that cannot be accounted for in models. Our study can, however, give a good insight of gold trading and how the price of gold should act in response to sudden changes in different macroeconomic variables.

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