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Correlation between Crude Oil and Gold

A Thesis Submitted in Partial Fulfillment
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CORRELATION BETWEEN CRUDE OIL AND GOLD WITH REGARD TO THE USD INDEX

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DECLARATION

I hereby declare that this thesis is entirely my own work and that it has not been submitted as an exercise for a degree at any other University.

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ABSTRACT

Oil and Gold are considered to be the most two strategic commodities. Crude oil is the world's most frequently transacted commodity while gold has a leading position among the main precious metals. This thesis examines empirically the relationship between gold prices, oil prices and US dollar index. Monthly data for gold prices, oil prices, US dollar index and other controlled variables over a period of 20 years were selected from Bloomberg platform. This thesis uses a unit root test and the Johansen test to check for the existence of cointegration between each pair of selected variables. Further this thesis uses Granger test to verify which commodity is affecting the price of the other. Our findings suggest a long run relationship between crude oil prices and gold prices. Granger causality test reveals causal links between gold and oil price levels. It shows that there exists a one way feedback relationship running from crude oil prices to gold prices.

Keywords: Crude Oil, Gold, US Dollar Index, Unit root test, Johanson test, Granger test.

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Chapter 1

Introduction

1.1 Introduction

Commodities are at the root of everyone's lives. They vary from the milk in babies' bottles and food in people plates, to the gas in every vehicle and the jewellery on ladies chests. This is why the prices of such a class affect people worldwide and reflect overall economy's performance. When in recession, commodity prices, especially the most basic ones, will significantly increase, reflecting uncertainty in the market. The best example is people lining up for bread in front of bakery doors whenever distress is in order. Of particular importance, this work will address two major commodities: gold and oil.

As far as five thousand years ago, gold can be seen as the single medium of exchange that has really survived the various shocks in the economy. This is why, whenever examining macro economy, people always turn toward gold investments. The main reason is that gold preserves its worth and plays well the role of a good hedge against inflation. This role is well demonstrated in stock market crashes where the gold always moves upwards. Characterized as an inflation hedge providing indemnity against deflationary recessions, gold was more preferable than fiat money. This is mainly because, unlike gold, money depended on the issuer's nation performance, money printing, and competitive exchange rate depreciation (Wang, M. et al. 2010). Whereas, the supply of gold mainly depends on its availability as a natural resource; it never counts on any country's wellbeing. As for gold demand, four main parties play a major role in the following order of market share: the jewellery business, private investment, central banks, and finally fabrication. It is important to stress on the fact that although priced solely in Dollar, these demands are considered significant on worldwide level,

gold being considered as an investment asset internationally. Besides, another identically important asset, considered as a consumption asset, has also shined in the market and that is crude oil.

Crude oil is a non-renewable scarce resource. The supply of oil acquired a particular character in the sense that oil producing countries became aware that a barrel extracted today will cease to exist tomorrow. In addition, while exploring historical data, one can conclude that oil prices instabilities can significantly influence the economy. That is, each time oil prices increase significantly, economy tumbles into collapse. Hereafter oil price, also quoted merely in Dollar, is a principal sign of economy's wellbeing (Wang, M. et al. 2010). Accordingly, the study of those two commodities price movement has earned great importance among investors and policy makers since a change in the price of these commodities could have an impact on other assets pricing as well as on economic growth for any given country. More importantly, whenever a relation among those "precious commodities" was suspected, more interest was concentrated for the study.

1.2 Need for the study

Crude oil is the world's most frequently transacted commodity while gold has a leading position among the main precious metals. In addition these two main commodities are traded in US dollar. Furthermore, these two commodities are considered to be the most two strategic commodities as they are among the major determinants of economic growth worldwide. Therefore examining the relationship between these two commodities is very important to policy makers and portfolio managers. For instance, this study would equip portfolio managers with tools for either hedging or simply price betting on these two major commodities.

1.3 Purpose of the study

The objective of this thesis is to examine empirically the relationship between prices of oil, gold and US dollar index. Particularly, this thesis attempts to address the following questions: Is there a causal and directional relationship between gold, oil and US dollar index? Is the relationship between their price weak or strong? Are they only affected by major common macroeconomic variables? Who drives who?

1.4 Brief overview of all chapters

Chapter 2 examines the relationship between crude oil and gold prices in the literature review. It covers the historical background of both commodities. Further this chapter looks at the determinants of both gold and oil prices and discusses the empirical relationship between them. Chapter 3 presents the methodology to be followed in this thesis. It elaborates on data collection and variables definition. It specifies the tests to be used as well as the statistical software. Chapter 4 shows the main findings of this thesis. It presents the results from the unit root test, the cointegration test as well as the Granger causality test. Chapter 5 discusses the main findings of this thesis and proposes its managerial implications it also shows the limitations and proposes further studies.

Chapter 2

Review of Literature

2.1 Introduction

Oil and gold, among others, are the two strategic commodities which have received much attention recently, partly due to the surges in their prices and the increases in their economic uses. Crude oil is the world's most commonly traded commodity, of which the price is the most volatile and may lead the price procession in the commodity market. Gold has a critical position among the major precious metal class, even considered the leader of the precious metal pack as increases in its prices seem to lead to parallel movements in the prices of other precious metals. Moreover, gold is not only an industrial commodity but also an investment asset which is commonly known as a "safe haven" to avoid the increasing risk in the financial markets. Using gold is, among others, one of risk management tools in hedging and diversifying commodity portfolios. Investors in both advanced and emerging markets often switch between oil and gold or combine them to diversify their portfolios. Policy makers are always watching the prices of these two major commodities as their prices can affect their economic policy. This chapter discusses the importance of these two main commodities. First, an overview of the history of Gold will be presented. Then, it will be shown why Gold acquired such an importance, how did it become a medium of exchange. Both long run and short run determinants of Gold prices will be tackled. Next, crude oil will also be under examination. All three oil crisis will be summarized and determinants of its price increase for the last decade will be analyzed. This will be followed by an examination of the GOR, Gold/Oil Ratio, and an assessment of both gold and crude oil pricing. Finally, a brief of all empirical work studying the main macro factors affecting those two commodities along with the relationship between their prices will be presented.

2.2 History of Gold

Throughout old history, gold was first discovered in its natural state: "a yellow nugget". Its brightness, manipulability and fight against blemish gave it greater value being favorable for production. The Greeks extracted gold out of the Mediterranean and Middle Eastern areas as far as 550 B.C. Gold has managed to become a measurable unit of value, a monetary standard that has made world economies possible. During the classic period of Greek and Roman empires, gold mutually traveled to India in exchange for spices and to China in return for silk. At the summit of the Empire, around the period of 98 A.C. to 160 A. C., Roman gold coins were dispersed from Britain to North Africa and Egypt. Money was created: It was gold.

The three P's (Portable, Private and Permanent) have acquired gold its monetary form. Hence, two gold standards have dominated international monetary systems following periods of economic depressions:

- The Gold Standard of 1870–1914
- The Gold Exchange Standard of the inter-war years. (Bordo and Rockoff,1996)

The gold standard stated that the purchase or sale of paper currency is transacted in exchange of gold. The theory lies on the fact that such fixing facilitates trust in the monetary system. This is mainly because gold does not carry any economic risk. Around the 18th century, central banks printed a lot of paper money which increased supply of money tremendously and eventually depreciated currencies. By linking paper currency to gold, society tied the capability of any central bank to supply money equal to the quantity of gold in its possession and thus would work impressively as a reducer for potential run-away inflation. Such fact rendered huge confidence in the currency as people were certain that at any time they were able to redeem paper currency they will

be compensated with gold. Such a fact lays conditions for better economic activity and greater financial stability. (Darista, J. 2009)

Yet, the restraint of the gold standard has damaged the plasticity necessary to respond to crises (Darista, J. 2009). As such, policy makers could not stimulate the economy in times of needs through monetary policies. Those policies consisting of an increase of money supply by central banks through three types of actions in order to stimulate the economy and avoid economic depression:

1. Open market operations, which is the purchase of treasury bills from the market. As such, there will be increased available liquidity in the market.
2. A decrease in the reserve requirements, in order for commercial banks to have more money in their vaults to lend to people at times of recession.
3. A decrease in the Federal Fund Rate or the rate charged for interbank lending, attempting to increase such lending, and resulting in a boost of household and business credit facilities through banks in times of crises.

Eventually, that would result in more consumption raising aggregate expenditure in the economy. Such plan mainly aims to promote maximum employment, stable prices and moderate long term interest rates. Nevertheless, money supply was strictly linked to the supply of countries gold that is in turn linked to mine supply.

The severity of the system pulled countries down to a very destructive deflationary path during the interwar period. For example, in the late 1890's the US blamed the gold standard for economic problems during the presidential campaign of 1896 (World Gold Council, 2006). Economy needed a boost in order not to fall in a depression similar to the great depression in the 1930's where all countries, rich and poor, were severely

affected. However, limiting money supply to that of gold would make any increase of money supply an impossible action unless new mines were explored. After the chaos of the inter-war period, the desire for stability with fixed exchange rates was still seen as vital for trade. For more flexibility than the conventional gold standard, and hoping to avoid a repeated depression, most of the major countries asked for an exchange standard that joined together gold and foreign exchange.

This regime prepared the grounds for the Bretton Woods agreements right after the World War II. This system, signed at Bretton Woods in 1944, was considered as a chance to form a soothing global currency and guarantee monetary stability. As far as 1946, the system was fully operating through the International Bank for Reconstruction and Development (IBRD), also referred to as the World Bank and the International Monetary Fund (IMF) that were established at the time. It included that the USA was to exchange its dollars into gold at the rate of $35 an ounce. Other currencies kept their par values related to the U.S. Dollar. Unlike the fixed price of the dollar, the worth of different currencies was determined by market forces of supply and demand. Supply, on one hand, determined by either monetary policy discussed earlier or fiscal policies which are changes in government spending also affecting money flow into or out of the nation. That is, every time governments increased their spending in order to increase money supply in the market, hence seeking an expansionary monetary policy. Inversely, governments decreased their spending aiming for a contractionary policy. On the other hand, demand is caused by both transactions and speculation. The rate could vary by 2% up or down margin without any intervention needed. (Dam, K. 1982)

In 1944, and for the period of 25 years when the Bretton Woods agreement was applied, the whole economy developed quickly. Governments were able to moisten economic instabilities and downturns were minor. However, sprains started to appear in the 1960s for many reasons:

- First, the Bretton Woods missed the incorporation of provisions that creates reserves. It only assumed that the production of gold solely would be enough to maintain the funding development and that every short run troubles could be treated through the borrowing regimes. Being in an era of post war, all nations required tremendous funding, way above the system's handling capability.
- Second, Gold had an open market in London. A conflict surged between the fixed price of gold ($35/ounce) and its open market value, which reached for example the value of $45/ounce during the Cuban missile crisis in 1962. Such price discrepancy generated uncertainty and market disequilibrium.
- Third, the Bretton Woods Agreement did not take into consideration reserve growth examination. Only gold and the U.S. Dollar were considered as reserves. But gold production being lagging, dollar reserves had to increase in order to cover the variation of lagging gold accessibility. That was reflected by a growing U.S. current account deficit which exhausted US gold reserves and the dollar lost enormous purchasing power during and after World War II.

For all the above reasons, on August 15, 1971, President Richard Nixon suspended the convertibility of dollars into gold, effectively ending the gold standard by 1971. Finally, the United States had to abandon the fixed value of the dollar and allow it to "float". Since then, both gold and Dollar prices were free to adjust themselves independent from one another and only based on supply and demand. (Bordo, M., & Eichengreen, B. 1993)

2.3 Determinants of Gold prices

This project will discuss the determinants of gold's price from short run and long run perspective.

2.3.1 The Demand for Gold

There are two components that contribute to gold prices.

1) First is the actual use of gold by jewelers or for industrial users such as electronic parts. This constituent implies that the higher the price of gold, the less is the demand for its use. While the least the demand from this factor does not necessarily affect the price of gold. This is simply because the price of gold is determined by investors who buy or sell this commodity for investment purposes rather than consumption reasons.

2) Second, the demand for gold as an asset for investment purposes will affect gold prices on the short run. This factor depends on a number of variables such as:

a) The Dollar exchange rate prospects. Gold being traded in dollar, the value of dollar with regard to other currencies would make it more or less expensive and thus affecting its demand.

b) Inflationary anticipations, as mentioned previously, gold is considered as an effective inflation hedge. As inflation is seen to increase, so is the demand for gold. That is because this commodity will not lose its monetary value whereas currency would lose its purchasing power substantially.

c) "Fear". Being considered as a "safe haven", gold is the number one refuge from any uncertainties in the market being independent of any nation's health and performance.

d) The lack of correlation with other assets. It is believed that gold has a negative correlation of returns or beta with regard to different stocks. This implies:

factors that causes stock market prices to decrease, at the same time affect gold prices to increase. Hence, the effectiveness of an instrument to decrease portfolio risk being inversely related to beta, holding gold would play the role of a safe haven whenever returns on stock markets become negatives for some short period of time. (Levin, E. and Wright, R. 2006)

2.3.2 Short run prices

The empirical work done on short run disturbances shows that:

- U.S. and world inflation changes necessitate an inflation hedge. That being the gold itself, inflation is than supposed to increase the demand for this precious metal and hence raising its price.

- Rising world income increases demand for gold jewellery as living standards increase and that, in turn will raise gold price.

- A fall in the dollar/world exchange rate raises the price of gold. Since a depreciated US dollar will make gold relatively cheaper for investors outside of the dollar area. The result would be an increase demand for gold raising the US dollar price of gold.

- An increase in the real interest rate would decrease the demand for gold lowering its price. The reason behind that is that increased real interest rates correspond to upper missed interest payments on holding government securities instead of gold.

- A climb in credit risk, political risk, uncertainty and turmoil will raise gold price as gold demand is anticipated to be high through periods of financial disorder having a negative beta.

- As crude oil prices place an upward pressure on inflation, automatically gold prices are affected: gold being an inflation hedge. Beahm (2008) even argues that the relationship among the price of oil and gold is one of the main fundamentals driving precious metals prices.

2.3.3 Long run prices

In contrast, gold prices are also affected by long run factors. For instance, Levin and Wright (2006) empirical research supports the theory that long run prices of gold are tightly related with the general price level in the US; in other words, US inflation level. This relation can be spotted in the following figure:

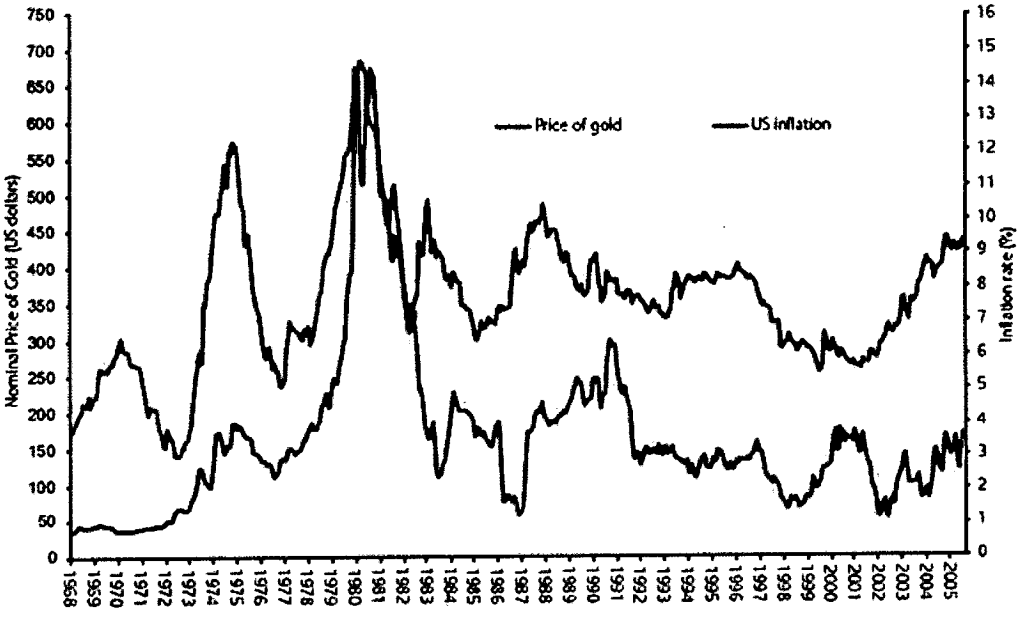

Figure 1: Price of gold and US inflation.

(Source: World Gold Council, 2010)

Moreover, after testing empirically, Levin and Wright conclude that the price of gold and the overall price level in the US move in unity at the 95% confidence level. However some short term deviations from the norm may occur along the way caused by short term changes such as the US inflation rate, inflation volatility, credit risk, the US dollar trade-weighted exchange rate and the gold lease rate. This is mainly seen during periods of stagnant economies where the level of inflation is too low or during financial crisis like that of 2008 as seen on the figure below. Whenever such deviations occur, it takes approximately five years for the long term relation between gold prices and the general price level in the US to be reestablished.

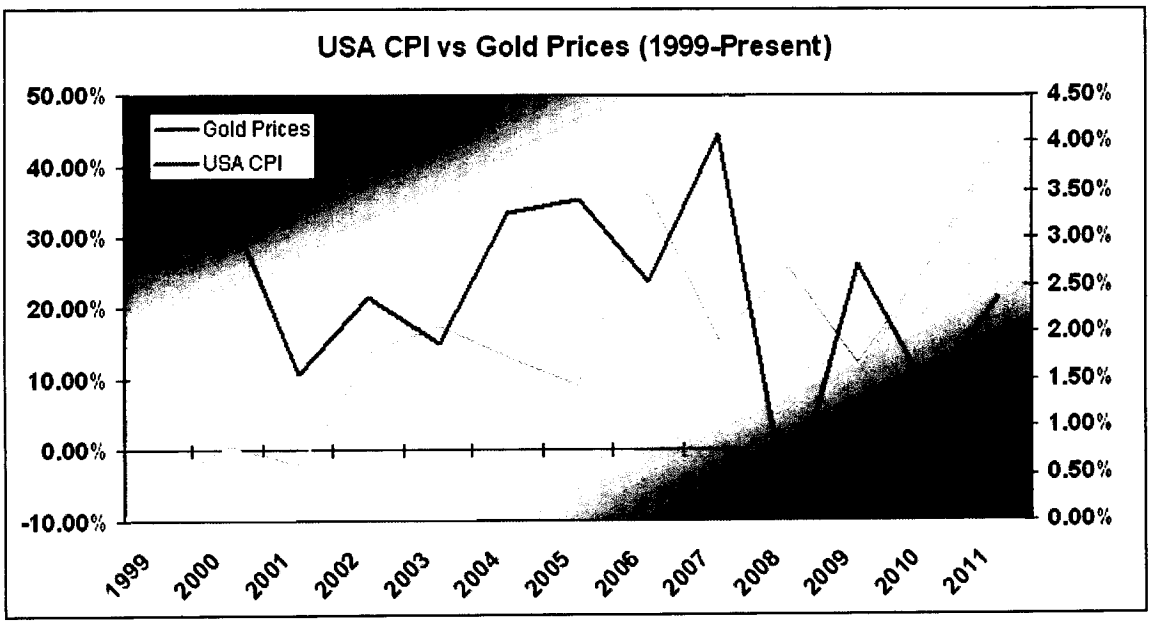

Figure 2: USA CPI vs. Gold Prices (1999-2011).

(Source: Pragmatic Capitalism.)

2.4 History of Crude Oil

Crude oil is a major player in our world. Even though scarce, it is indispensable due to its energy supplying role through transportation, industry, heating ...In his article posted by Bloomberg, Rubin, J. (2012), cited that for the past century, cheap oil powered worldwide economic growth. For example, back when oil was priced at $20/ barrel, the U.S. leaded global economic growth, Federal Reserve ran budget surpluses and unemployment rate was at a 40 years low. However, for the last decade oil prices more than quadrupled distorting this perfect image. Many researchers associated increased oil prices with peace disruption. Notably, three oil crisis have already occurred throughout time, of which, two were during the 1970's and the third during the financial crisis of 2008.

2.4.1 First oil crisis

The Arab-Israeli war in 1973 caused the first oil crisis in 1973 right until 1978. Arab members of the OPEC met in Kuwait announcing isolation of oil supplies against states supporting Israel, which started the Yom Kippur War. Their claims mainly held:

- The Eastern oil producing countries could not tolerate a continuous increase of oil consumption of around 5% per annum while maintaining oil prices constant. When these oil producing countries are buying their goods from the rest of the world; they were paying inflation- priced goods. The Shah of Iran confirmed the rise in oil prices by claiming that whenever the wheat, cement or sugar bought from Western countries have increased around 300%, what should hold the price of oil bought from the East of behaving the same .Knowing that the West bought that crude and sold it back processed to those oil mother countries hundred times the price they have bought it initially.
- Absolute verification of level of production to keep prices "artificially" leading of crude. Since demand for crude oil is somehow inelastic; demand falls little whenever

price is increased. Therefore, prices should be raised drastically in order to reduce demand to be in better equilibrium with the "limited and lesser" supply of oil.

The prompt economic effects of that period were the immediate increase of oil prices, up to four times their earlier value, reaching $12/barrel. Middle Eastern countries that have long been dominated by industrial powers seemed to gain some strength of their own having gained control over an essential commodity, the "oil weapon". This oil shock has resulted in a period of increased inflation, reduced productivity, lower economic growth and recession. (Makhoul, T. 2010)

2.4.2 Second oil crisis

The second oil crisis was in 1979.It was caused by the Iranian revolution and later by the Iraqi/Iranian war in 1980. All throughout the period of 1978 and 1981, the disruption of Iranian exports encouraged crude oil prices to increase. In consequence of the Iranian revolution and the Iran-Iraq war, the price of oil was suddenly multiplied by 2.4 between 1978 and 1981leading to a price increase from $ 15.51 to $ 34.07. (Makhoul, T. 2010)
It is impressive how during both of these crisis, gold prices have replicated the changes experienced by crude oil. It is only expected, since both commodities are considered as a "safe haven" in times where everything else is endangered. Below, two charts illustrate crude and gold response to those two crises. We can clearly spot the resemblance in reaction of those two commodities in response to those specific incidences.

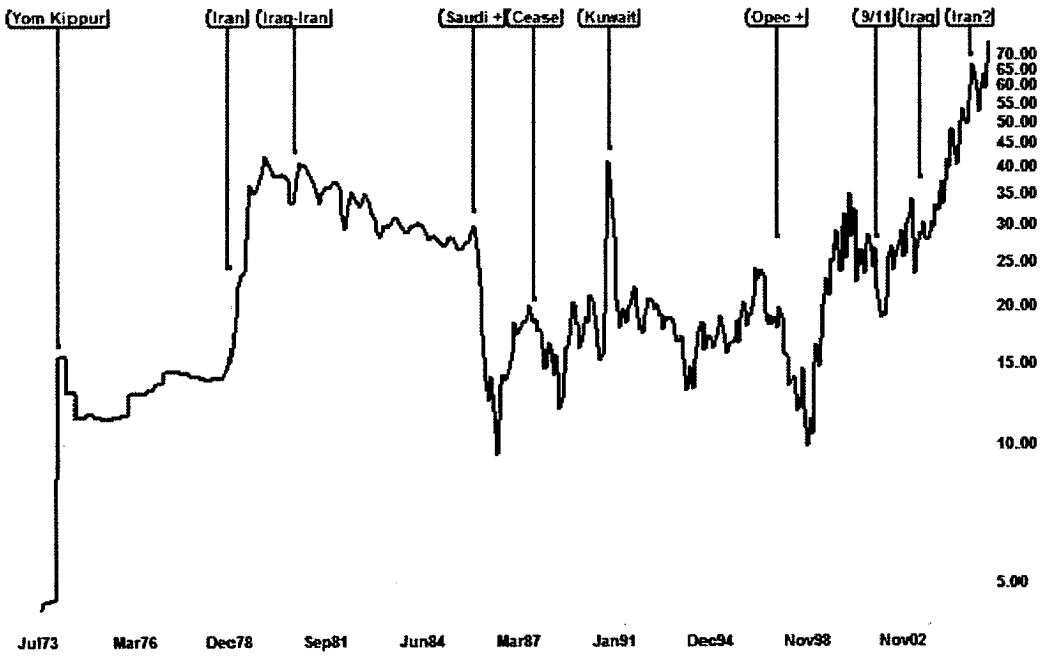

Figure 3: Monthly Brent Crude prices.

(Source: Global Financial Data (2012).)

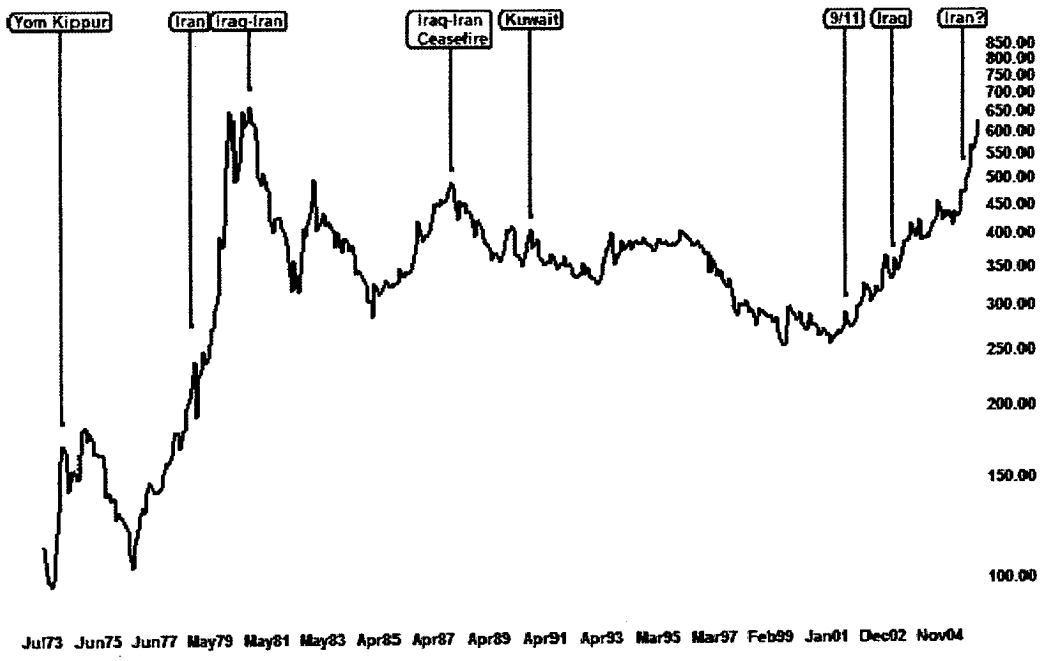

Figure 4: Monthly XAU London prices.

(Source: Global Financial Data, 2012)

2.4.3 Third oil crisis

The third economic crisis of 2008-2010 can be described as a fall that joins the most developed countries in the world. It started as a result of a period of easy credit, inappropriate supervision and regulation or simply financial greed. Following the decline in shares prices and housing, large U.S. and European banks lost large sums of money. On December 2007, the United States was the first to start falling. Several European countries followed the lead of the US in 2008 until the entire euro area sunk. Only France was able to hold until 2009 before it fell into real recession. This crisis, considered as the worse since the great depression, was characterized by a sharp increase in oil prices and agricultural products mainly driven by speculation. Financial markets were bearish; speculators were oriented toward safer choices of investment, which is raw materials and especially oil. Such preference inflated the price of that class. On the 2nd of January 2008, oil prices outstripped the $ 100 per barrel level as a result of a large decrease in demand for equities and other financial instruments that seemed very risky. (Makhoul, T. 2010)

2.5 Reasons behind crude oil prices increase:

Oil prices are determined by two factors. The first and very basic to any entity that is purchased and sold is supply and demand. The basic is very clear, as demand increases, price increases and conversely as supply is limited, price increases as well. The second factor is market sentiment. Since oil is a necessity commodity, its price is dependent of market sentiment, especially during critical periods where people fear losing their supply. In this section, a list of factors behind the past crude oil prices increase will be discussed:

2.5.1 China: A giant appetite

China has become one of the main suppliers of capital through Asian countries. This resulted in increased industrial machines therefore a bigger appetite for oil. Starting 1978, Chinese use of vehicle (cars, buses or trucks) has varied from 1.36 million motor vehicles to 33 million vehicles by the end of 2005.During the period of 1995- 2007, oil consumption has risen 130% in China against 17% in the United States. Hence, the vulnerability of China's energy is transformed into a major concern for Chinese leaders. Transfers accounted for 27% of the total oil consumption in 1999. In 2002, consumption reached 37% and 47.5% in 2006. As for the period 2005 - 2020, Chinese oil consumption is expected to double, draining the correlation with respect to the Middle East, a region that should provide nearly two thirds of deliveries over the next decade instead of a rate of delivery of 48% in 1998. (Bhattacharyya, 1998)

2.5.2 India's anticipation to be the next China

According to Bhattacharyya (1998.), similarly to China, India has experienced strong economic growth. Since 1990, income per owner in India has grown by 50%. This has resulted in higher sensitivity for energy and particularly oil. The country is already witnessing an increase of 70% of its foreign imports of oil. The expected proportion will reach 80% by 2015 and possibly 95% in 2030.At that time; India will be the third consumer of oil in the world after the United States and China. Even though the Indian government is rushing the study on the national territory of new resources, the anticipated results will not be satisfactory for a uniform increase in consumption. For the moment, oil stocks in India, especially those in Assam and Gujarat, constitute 0.5% of world reserves: a ratio three times less than that of China. The Middle East remains one of the leading suppliers in India with a proportion of 67%, followed by Nigeria (16%), Sudan (4.3%) and Venezuela (4%).

2.5.3 Under-investment in the infrastructure in the 90's

Taken from the IEF (2010), the response to the growing universal energy demand should be answered by energy consuming countries. Those countries must secure essential investments in energy related infrastructure including oil refineries and related facilities. It is also important to direct the necessary investment into the technological development of exploration, drilling and other operations. That is to mitigate the technological and financial risks involved in upstream development.

Furthermore, underinvestment in oil industry infrastructure keeps the door open for an energy distress. Whenever a global economic recovery is sending demand through the roof, the oil industry will have trouble delivering. Burri, P. (2008) estimates that about one fourth of the world's estimated recoverable oil resources have been produced until today. The draining in the supply and demand balance of energy resources is therefore not mainly a problem of geological reserves of oil. It is on the contrary due to a lack in the ability of production and transport infrastructure resulting from underinvestment by the industry in the 90's. He also adds that such a situation is hard to rectify in a short time, given the lengthy lead-time to bring new developments.

2.5.4 Risk premium on Crude

The recent burst in the price of crude is the risk premium the market approaches due to the uncertain outlook for the bigger crude producing Arab states. The risk premium is the minimum difference above the risk free rate that a person requires to take an uncertain bet and accept the risk of any investment. The dilemma for investors concerning crude oil is the risk premium" on that commodity that could persist for several months once any disorders in any of the producing countries surges. Hence, the "risk premium" receivers would be the senior and junior crude produces and the oilfield

service companies, like Suncor Energy Inc, Canadian Natural Resources Limited, Cenovus Energy Inc, Precision Drilling Corporation and the BMO Junior Oil Index ETF (ZJO).

2.6 Gold- Oil correlation analysis

Up until now, gold and crude oil have been examined separately and it has been induced that both commodities have some factors in common. They have both survived crisis, even outperformed, when all other instruments were hitting bottom. Their importance to the market have made them very crucial in any portfolio being considered as safe and negatively correlated to other market shares. In order to better assess the relation between crude oil and gold, a gold/oil ratio (GOR) was created as a barometer used as a "reality check" to some predictions. This ratio can be used as estimation whether gold or oil are overpriced or underpriced. It is calculated by dividing the price of an ounce of gold over the price of a barrel of crude oil. It follows that, whenever the current ratio is below 15.4: gold is either underpriced, or oil is too costly. Inversely, when the ratio is greater than 15.4, oil is either too cheap or gold is too expensive. (Lee, J. 2008) This can be spotted in the chart below:

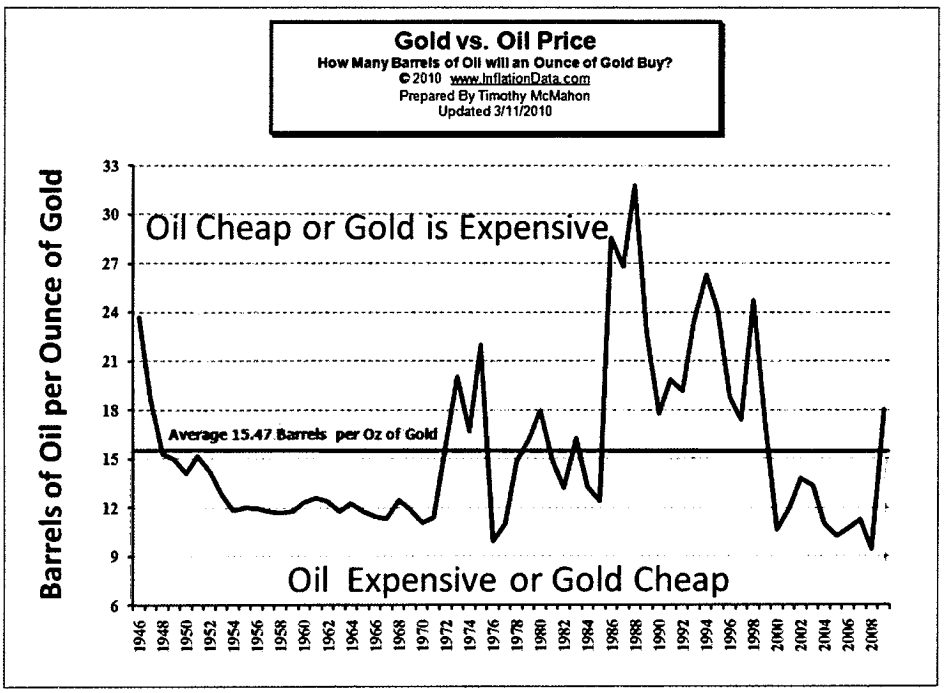

Figure 5: Gold vs. Oil Price: How many barrels of oil will an ounce of gold buy?

(Source: www.inflationdata.com by Timothy McMahon, 2010.)

A Washington time article by M, Jaeger (2012) empirically found that.0602 ounces of gold times the price of gold should be equal to that of a barrel of oil. The study was conducted with a standard error of just .421 per cent. That is, on average, the difference between these findings and reality is just about $6.10 dollars since 1986 with an accuracy of 99.579 percent.

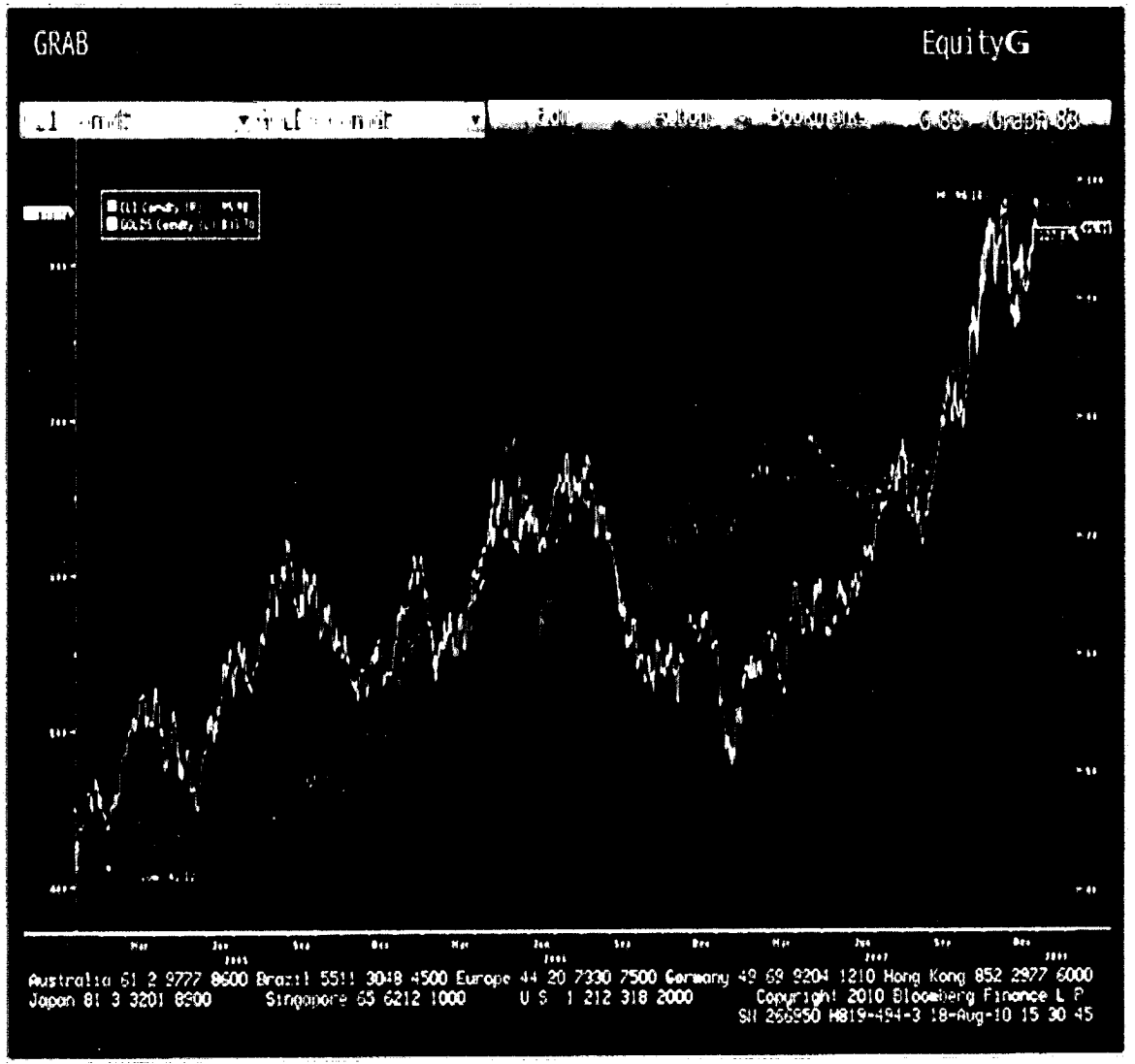

Figure 6: Gold and Crude oil prices.

(Source: Bloomberg)

Above is a graph representing the correlation between crude oil and gold that seems perfectly correlated before the subprime crisis that have started in 2007. In other words, whenever gold rises, crude oil tends to take the same path, and vice versa. However, we can spot in January 2007 that this correlation was reversed. Gold rose from $ 559 to $ 700, while the oil dropped from $ 65 to $ 50. So this correlation, just like any other, can

be broken down during a crisis. It is also clear that the relationship is slowly corrected right after, yet keeping a gap between their prices. This is mainly due to instability and thus a mismatch between supply and demand. In general, during the post-crisis period, the decrease in oil prices leads to a similar response in gold prices. The inverse implies for an increase; from where the usefulness of the Gold-Oil Ratio (GOR) derives. In other words, it is an indicator of how many barrel of oil can be purchased with one ounce of gold. Since 1985 this ratio was 16 with a standard deviation of 6: meaning that 95% of the time this ratio changes between 5 and 28.

For example, on the 25thof May, 2013, a barrel of oil is priced at $ 93.86 and an ounce of gold is around $ 1384.9. Calculating for the GOR:

$$1384.9/93.86= 14.75$$

So it could be concluded that the GOR being below 15.4, gold is either underpriced or oil is too costly. Based on the latest events of events, gold has decreased in price from the 1600 in the beginning of April, 2013 to a price even below than 1350 in mid-April, 2013. This happened following Cyprus having sold a part of its gold reserves early in April, 2013. It is possible to then agree that gold is being undervalued in this case.

Despite the undervalued price of gold, the GOR is still somewhere in the middle range of its interval: 5-28. Whereas, in 2008 this ratio was:

$$925/109 = 8.5$$

That is, the GOR was on the lower boundary of its range. However this anomaly did not last for long.

2.7 Related theories

2.7.1 Crude Oil

After examining the literature on crude oil prices, this section discusses different scholar's theories about this subject. Mainly, different studies agree that there is a tight bond between crude oil and the US Dollar, inflation, GDP, and interest rates.

- Crude oil and the US Dollar

The markets for crude oil are priced solely in US Dollar. However, being produced and consumed all over the globe, the appreciation or depreciation of the Dollar vis-a-vis other currencies will certainly affect oil prices in non US Dollar currencies. This implies that if ever one way directional movements between the US dollar and different currencies are extended and constant, two consequences are more likely:

- First, the currency movements will immediately show in crude oil prices. Being priced in Dollar, the demand for this commodity will be affected as it might become cheaper or more expensive for one unit of different currencies. In other words, as the Dollar depreciate, oil becomes cheaper to non US nations which will increase the demand for oil and in turn would increase its price based on the "Law of Demand". (Grisse, 2010)
- Second, those currency alterations will be reproduced in the Supply- Demand function for crude oil production and consumption of non US countries. The dollar price will affect oil producer's price setting conduct. Since most of oil producing countries pegs their currency to the Dollar, a depreciation of the Dollar will be directly related to decline in the purchasing power of oil proceeds. Those oil producers will benefit from a counterbalance of the Dollar depreciation by increasing the price of oil. (Turner, A. et al. 2011)

- Crude oil and inflation

Crude oil and inflation are often grouped in a cause and effect relationship. This can be explained by the fact that crude oil is a major input in every industry. It follows that every time crude oil prices increase, there will be a general cost increase in all industries. Then, it is only normal that this additional cost is reflected in the price of the final goods. This will eventually lead to an overall price increase, i. e. inflation. This relation is illustrated in the oil crisis of 1979 when oil prices rose from $3 a barrel in 1973 to $40 in 1979. As a result, the consumer price index (CPI), which is a measure of inflation, jumped from being 41.2 in 1973 to 86.3 in 1980. However this relation has weakened across time where, during the 1990's Gulf War oil crisis, crude oil prices almost doubled in six months from approximately $20 to nearly $40, nevertheless CPI remained relatively constant, growing from 134.6 in January 1991 to 137.9 in December 1991. This relationship detachment was more apparent during the oil price escalation from 1999 to 2005. The annual average nominal oil price rose from $16.56 to $50.04. During this same period, the CPI rose from 164.30 in January 1999 to 196.80 in December 2005. (Rubin, J. 2012)

- Crude oil and GDP

Allsopp, and Fattouh (2011) found that the Gross Domestic Product (GDP) or household income is the major determining factor of crude oil demand. For example, during the period of 2000-2010, the demand for oil in non OECD countries has increased drastically, around 13mb/d, due to a surge in incomes in emerging countries accompanied by an increase of car owning rate in these same countries. In addition, the EIA has conducted a study to complement such findings. They have studied the projection of global oil demand under five distinct scenarios of GDP growth: the reference case where growth in world real GDP is around 3.2 per cent yearly from 2007 to 2035. Followed by the high economic growth case, here 0.5 percentage points is inserted to the annual growth rate while in the low economic growth case, 0.5 percentage point is deducted from the reference case annual growth rates. Furthermore, in the high oil price case, world oil prices climb from $59 per barrel in 2009 to $210 per

barrel in 2035. Finally, in the low oil price case, prices of oil decline to $52 per barrel in 2015 and remain approximately at that real level through 2035. All these figures are compared to a world oil prices rise to $133 per barrel in 2035 in the reference case as shown in the figure below.

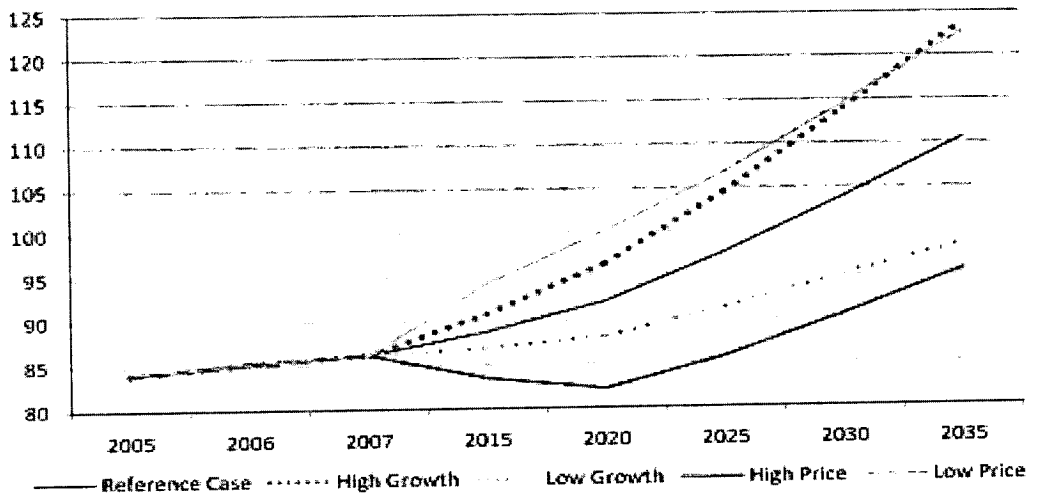

Figure 7 Projections of global oil demand in different scenarios (mb/d).

(Source: EIA)

- Crude oil and interest rates

Even if interest rate and crude oil do not seem to have a direct bond, they do exhibit a negative correlation. This is due to the increased borrowing whenever interest rates are low. As such people tend to open up more businesses and then consume more oil since any transportation and industry require the use of energy and more particularly oil. Having a limited supply of oil imposed by the OPEC, the bid price for oil will therefore increase. The opposite is also true: every time interest rate is increased, borrowing becomes expensive whereas saving becomes profitable. People tend to save their money and earn interest instead of using it into businesses and that will lead to a decreased demand on oil and thus a decrease in its price. (Grisse, C. 2010) This relation is proved empirically by Sardovsky (1999). He used vector auto regression analysis in order to investigate the relation between the three months US treasury interest rates and oil

prices. The findings proved that a sudden oil price raise is positively linked to the three months interest rate on the US treasury.

2.7.2 Gold

Similarly to crude oil, most of the studies conducted to determine gold prices have also found a link with the US Dollar, inflation, GDP, and interest rates.

- Gold and the US Dollar

In 2008, the IMF conducted a study showing that 40 to 50 percent of the time the gold price moves, it has been dollar related since 2002. This relation is judged to be, just like crude oil, a negative relation between gold markets and the US Dollar. This is mainly due to two facts:

- Gold being priced in Dollar, depreciation in Dollar prices will lead to a cheaper gold with regard to other currencies. This will lead to an increased demand for gold, eventually resulting to an increase in gold prices (O'Connel, F. 2012).

- Every time the dollar weakens, people turn onto gold as an effective alternative mean of store of value. This mainly includes dollar based investors who worry about the inflationary costs of a weak dollar. (Oxford economics, 2011)

This association between the gold and the dollar is confirmed in recent historical events. As shown in the figure below, in the late 1970 and 2002, for example, the dollar weakness was accompanied with rising gold prices. On the contrary, in the mid-1980s and late 1990s, a strong dollar prevailed and that rendered relatively low gold prices. (Oxford economics, 2011)

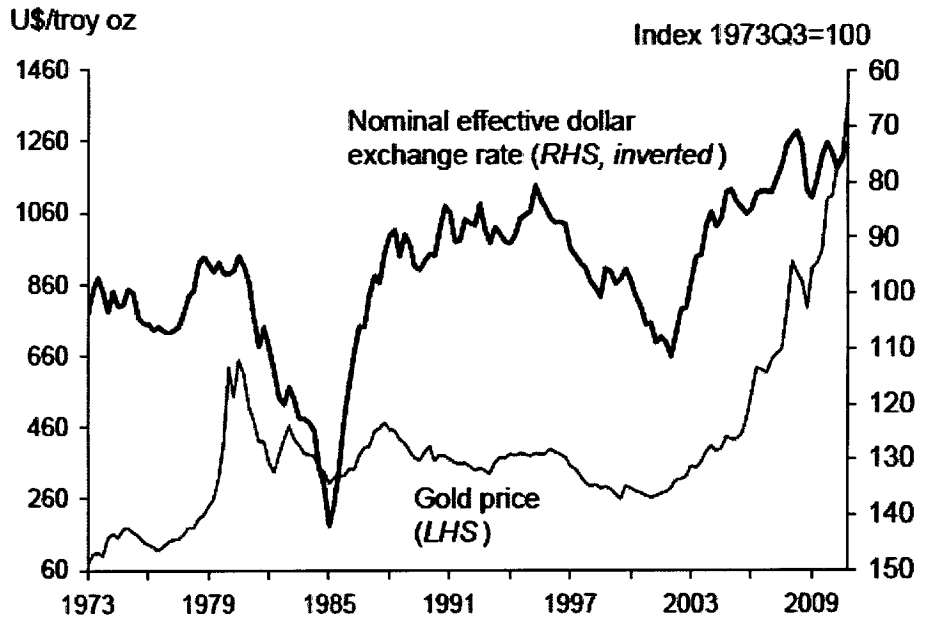

Figure 8 US dollar exchange rate and gold.

(Source: Oxford Economics/Haver Analytics)

- Gold and inflation

From being a medium of exchange back during the gold standard and Bretton Wood times, to becoming an investment vehicle, gold has successfully maintained its purchasing power. This is why, the tendency of gold to maintain its real term value has led gold to be considered as an inflation hedge worldwide. It follows that every time inflation mounts the demand of gold for investor portfolios increase in an attempt to protect oneself against inflation. A study conducted by Oxford economics (2011) observes the behavior of gold prices under alternative scenarios of inflation and rates it on a scale of 1 to 5 as opposed to equities, bonds cash and house prices:

- In a period called the baseline where economic recovery is steady, inflation is moderate and financial conditions are gradually normalized, gold is scored as 1

or worse performing. This is mainly because people tend to prefer equities in such periods having higher yields of return than gold.

- In the deflation scenario that is characterized by massive financial distress that leads to renewed recession and a decrease in consumer prices, gold is rated as 3. This mainly because investors tend to prefer cash in such times having an amplified purchasing power and increased value. Followed by bonds characterized by a steady flow of streams preset by their yield upon issuance.

- In a stagflation period where inflation and interest rates are higher but growth is weaker from that in the baseline, gold is rated as 2. Here capital holders rather hold cash, than real estate and equities before turning toward gold. This is mainly due to the increased general prices which characterize those investments with increased capital gains and higher interests in the market as opposed to gold that has no actual yield of its own.

- Finally, in inflation periods where wage- price spiral and lax monetary policy that pushes inflation to double leading to a severe monetary tightening and so recession, gold is qualified as the best performing due to its inflation hedging attribute explained earlier.

- Gold and GDP

Gold is also affected by GDP, being an indicator of economies health. For example, in times of recession, a GDP higher than expected is an indicator that the economy is recovering and inversely, a lower GDP will raise uncertainty about economic welfare. It is than normal to conclude that whenever GDP is lower, investors will turn toward gold investment in order to hedge against market uncertainty (Chau, M. 2012). In their study, Sharma, M. and Aggarwal, R. (2012) examine the relation between gold and GDP of the world's larger gold- holding economies. After calculating the coefficient of multiple correlation that measure the relation between gold and GDP based on the regression

equation and coefficient of determination that indicates the percentage of variation in gold prices explained by the GDP of those countries in the regression equation. Results show that seven out of nine economies used together best foresee movements in gold prices. Additionally whenever GDP of each country regressed separately with gold prices, one can conclude that gold is least correlated with Italy's GDP and most correlated with Brazil's GDP. As for the US, being the world's highest gold holding country, gold prices are only moderately correlated with its GDP.

- Gold and interest rates

Another factor affecting gold prices is real interest rates. Gold having no yield of its own, its return is mainly measured by calculating the opportunity cost of holding gold against real interest rate in the market. Thus, as real interest rate increases, the cost of holding gold in ones' portfolio follows and decreases with a real interest rate decrease. This is mainly illustrated by the figure below: during the 1970's when real interest rates stayed low for lengthy periods of time gold price jumped from 37 USD/Oz in 1970, to 590 USD/OZ in 1980. And during the 1980's, when interest rates were considerably positive in an attempt of global central banks to squeeze out inflationary pressures, gold had had declined from its 1980 peak reaching 327 USD/Oz in 1985 and 391 USD/Oz in 1990. Funds were diverted into other assets considered more profitable than gold with such high interest rates. (Oxford economics, 2011)

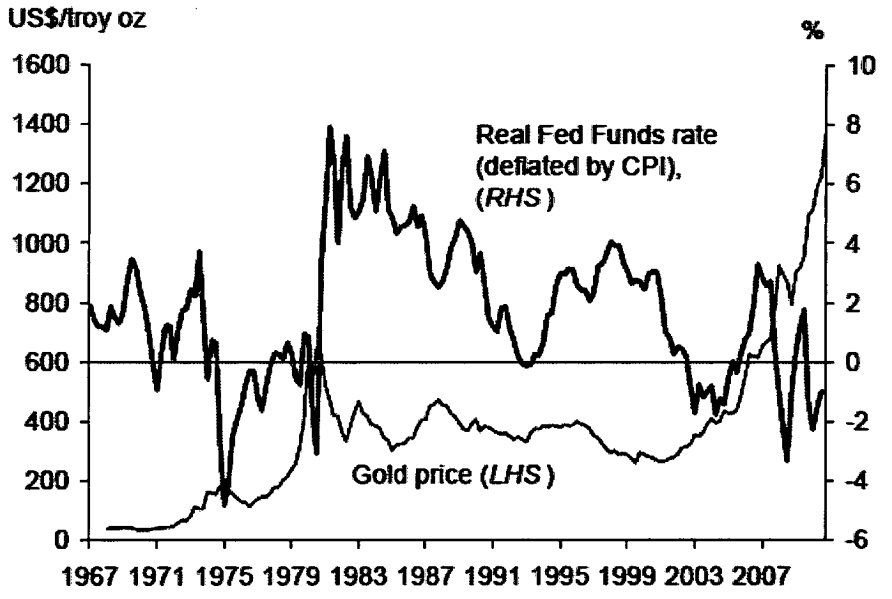

Figure 9 Real interest rates and gold.

(Source: Oxford Economics/Haver Analytics)

Based on these findings for gold and oil separately, it is clear that the reaction of both commodities to the US dollar, inflation, GDP and interest rates is the same. They are both positively related with inflation and GDP and negatively linked to the US Dollar and interest rates. It is then obvious that a direct relation exists between crude oil and gold with regard to those mentioned economic factors.

2.8 Empirical research

After examining the literature about the correlation between crude oil prices and gold, three main hypotheses are spotted:

2.8.1 First hypothesis: Crude oil prices affect gold prices

First, Furlong et al. (1996) and Narayan et al (2010) demonstrates that oil prices rise is mainly followed by approximately an overall price rise. Then, every time inflation mounts, the price of gold tracks. Subsequently, investors can guess gold price by the dollar index and inflation index. Moreover, this hypothesis is also strengthened by the fact that gold is mostly considered as an inflation hedge. Each time crude prices increase, inflation aggravates. It follows that the demand for gold increases resulting in its price increase. Hooker (2002) followed by Hunt (2006) both have proved this relation empirically by proving that every time the general price level or inflation increases, commodities as a whole increase. Gold being a commodity, an increase in the price level will result in an increase in gold prices as well. Second, Melvin and Sultan (1990) highlighted the effect on gold prices considering the export revenue channel. They have found that, gold was the crucial element of the international reserve portfolio of nearly all countries, including oil producing ones. Hence, whenever oil prices increase, oil exporters' proceeds from oil sale increase as well. Gold being a major share of oil exporters' portfolio, it follows that the gold price level also rises as the demand for it also increases as a fraction to their share. And this is why many believe that an oil price increase leads to a similar reaction in gold prices. Liao and Chen (2008) proved the relation between oil prices and gold prices and individual sub-indices in Taiwan using GARCH and TGARCH. They have found that oil price changes affect gold prices without the opposite being true. Upon examination of long term relationship among these two commodities, Zhang et al (2010) found an important cointegration between their prices. Their showed that changes in crude oil prices affected significantly and linear Granger changes in gold prices. They also found that at 10

percent significance level, no significant nonlinear Granger causality between the two commodities under study: their interactive mechanism is direct. Also Nayaran et al (2010) evaluated the long run relation of oil and gold future prices at different maturities. They have observed a cointegration relationship for all pairs of spots and futures gold and oil prices. Therefore, these findings imply that oil prices can be used to predict gold prices.

2.8.2 Second hypothesis: Crude oil prices and gold are not interlinked; they are both affected by the same macro-economic factors.

Simakova (2011) studies that both gold and oil are affected by inflation, industry, interest rates and stock prices of gold mining companies. Also, Subarna et al. (2012) proved the existence of cointegration among crude oil, gold and the US Dollar by implementing common trend, Granger causality and volatility spillover for these macro variables. Yet, they find that not all variables moved simultaneously. Stock price and gold price are more prone to move independently while oil price and exchange rates are expected to be affected by additional factors. Bapna, I. et al (2013) conducted a research where they have found important co-relationship in the form of correlation between the exchange rate and gold on crude oil. They have also concluded that there is a long term cointegration and a unit root among the variables due to non-stationary tendency. In their work, Sari et al (2010), test this above hypothesis. They have used daily time series data, to determine the directional relationship between the spot prices of four precious metals, of which gold prices, along with oil and the USD/EUR exchange rate. A weak and asymmetric relationship is found between oil price and gold price returns. Especially, gold prices don't explain oil prices but oil prices might affect gold prices up to only 1.7 percent. Zhang et al (2010) uses Granger causality to highlight the high correlation between the US dollar and the price change of both crude and gold.

2.8.3 Third hypothesis: Crude oil prices affect gold prices negatively as those raise the cost gold of mining companies.

This third hypothesis have not been addressed by many researchers, however its existence is worth mentioning for further investigation purposes. It states that just like any industry, a direct link exists between crude oil as a cost and gold mine companies revenues. Since mining requires the use of energy, and energy being more or less indexed to oil prices, an increase in oil prices leaves mining companies with decreased revenue from gold sale. This view is addressed by a recent article posted in the Daily Capitalist (2011). It stresses that whenever crude oil prices are down; this is never bad news for gold mining companies. Mainly because some believe that gold prices will not necessarily follow. Then, a decrease in oil prices means that the cost associated with the price of gold is reduced leaving a larger profit bracket. However, if ever there was a trend imitation, the weight of the decrease and that of the profit margin should be tackled in order to properly assess whether this change in oil prices have affected gold prices positively or negatively.

2.9 Conclusion

In a nutshell, this part has tried to grasp all literature about crude oil and gold. Starting with a brief history of gold, this project examines how gold was used as a medium of exchange between buyers and sellers. In other words, how gold was money in earlier times. Then this project considers the changes this essential commodity has experienced over time. An examination is conducted regarding the Gold Standard of 1870–1914 and the Gold Exchange Standard of the inter-war years where paper money was immediately exchangeable into gold. Later on, a move toward a more flexible system erupted due to the lack of elasticity of the gold standard to respond in times of crisis. This is where the Bretton Wood system took place: the gold was linked to the Dollar. Finally, as this system also failed to completely answer the deficits in the US currency, all currencies were "set free" to float on their own. Later on, the study of

determinants of gold price are tackled in the short run, for instance living standards, the dollar/world exchange rate, real interest rate, credit risk, political risk, uncertainty and turmoil. In the long run gold prices are affected mainly by the US inflation level. Next, a move toward an overview of crude oil history takes place. Three oil crises are examined along with their effect on crude oil prices first, than on gold prices. Later on, the reasons behind the important increase in crude oil prices during the last decade are examined. Namely, the huge demand for oil from China, than that of India that is following the lead of China, the under investment in the infrastructure in the 90's, and the risk premium on crudeare all examined. Once identical behavior to historical events and economic factors is noted, a relation between crude oil and gold is to be studied. This is done through the study of the Gold- Oil correlation analysis where no direct link between the two commodities is detected.

Afterward, related theories to our subject of study are presented where an inverse relation between crude oil and gold with regard to the US dollar and interest rates is identified along with a positive connection with inflation and GDP. Based on changes in those economic factors, demand for oil and gold will either increase or decrease affecting their prices with response to the law of demand. This is why, a relation between crude oil prices and gold prices with regard to the US Dollar, inflation, GDP, and interest rate is determined for further research. Finally, the last part of this chapter focuses solely on key empirical work that covers the main factors affecting these two commodities prices and most importantly, the relationship between them. The first school of thinking states that oil prices affect gold prices either through inflation channels or the increased proceeds from oil sale which leaves oil producers with an increased amount to be invested in gold as part of their investing portfolio. Second, a relation among those two commodities is denied. The replication in price movement is explained through the fact that the same macro variables affect both crude oil and gold in the same manner. And third, an inverse relation is claimed, where a decrease in the price of crude oil would decrease costs incurred by gold mining companies and therefore increasing their earnings. Finally, it is clear that the conclusions about correlation between crude oil and gold are still not decisive.

Chapter 3
Procedures and Methodology

3.1. Introduction

Gold and oil are the two most important commodities exchanged on the market. The previous chapter explains how gold evolved from being money used as a medium of exchange to becoming the most important investment asset. It also described crude oil's role as a consumption asset. Mainly, whenever crude oil prices increase substantially, an economic crisis is most probable driving investors toward the ultimate inflation hedge: gold. Then, every time markets fall during crisis, the main two survivors are gold and oil. Hence, a positive relation is suspected among those two commodities themselves. Later on, empirical work on those two commodities has been considered. Mainly, studies agree that crude oil and gold relation with the US Dollar index and interest rates is negative while their relation with GDP and inflation is found to be positive.

As a result, this thesis will attempt to answer the following three questions:*(i)* Are crude oil and gold correlated? *(ii)* Which one is leading and how? *(iii)*What are the major factors influencing both crude oil and gold's behavior?

The chapter is organized as follows. In section two we summarize the hypotheses that will be tested. In the third section the selected variables will be described along with the sample size. In section four we describe the statistical package used in this thesis. Finally, in section five we present the methodology used to answer the three research questions. I this section we give an overview about Dickey Fuller unit root test, the Ljung-Box test of autocorrelation, the Johansen cointegration test, and the Granger causality test.

3.2. Hypotheses

In order to investigate the price relation between gold and crude oil, the following two hypotheses are considered. *(i)* Oil and gold have a unidirectional relationship that runs from crude oil to gold. *(ii)* Gold and oil are not correlated; they are solely affected by common macroeconomic factors.

3.3. Selected variables and sample size

In order to conduct the study, time series were exported from Bloomberg station. Those will constitute a sequence of data point measured at successive points spaced at uniform time intervals. These series will be made up of monthly prices for crude oil, gold, the US Dollar Index, and US CPI. The time series design engages consecutive observations throughout a planned interference and assesses the features of the change procedure. It serves many simultaneous purposes:

- First, it is descriptive. Such a characteristic is mostly significant when the intervention extends over an extensive period of time. It is the single mean to provide a constant trace of fluctuations in experimental variables over the whole path of the series.
- Second, the time series design operates as a heuristic device. That is, when coupled with historical log of likely relevant non-experimental events, the time series is a helpful foundation of post-hoc hypotheses concerning experimental, although unintentional, changes in program variables.
- Third, the time series serves up as a basis of hypotheses about nearly all promising choices, and later on as a feedback cause about the outcomes and efficacy of such results where other treatment programs necessitate practical managerial decisions.

- Forth, the time series can work as a quasi-experimental devise for planned interventions imbedded in the whole program every time a control group is unlikely.

Additionally, if ever sample size does not cover an appropriate time period, results might be misleading by accounting for results of a certain reaction to a singular event. Also, results might fail to account for cyclical behavior. (John, M. 1969)

In order to avoid the above mentioned limitation, monthly data from December 1992 till December 2012 have been used. This period is mainly chosen for being considered representative of all economic aspects having witnessed all the following events:

- A continuous phase of US economy growth, until the mid-2000;
- The introduction of the Euro in 1999;
- The September 11 attack in 2001;
- The increasing role of the emerging economies: Brazil, Russia, India, and China, also referred at as "BRIC";
- The global financial crisis of 2008.

The variables used can be classified as endogenous and exogenous variables. The endogenous variables defined as factors in the causal model having values determined by states of other variables in the system are:

Crude Oil: World crude oil is represented by the West Texas Intermediate (WTI) crude oil prices, also known as Texas Light Sweet. This oil is the world's most liquid and largest volume futures contract trading forum for crude oil and is mainly used as a benchmark in the pricing of oil. It is assigned the quality of "light" due to its relative low density, and "sweet" due to its light sulfur concentration. This commodity is traded on the Chicago Mercantile Exchange in the form of futures contracts and is quoted in Dollars.

Gold: Exchange traded gold is a hedging tool for users and even producers of gold. They offer a number of facilities like global price discovery, portfolio diversification, permanent trading opportunities, and may replace gold bullion, coins, and mining stocks. Gold prices used for the purpose of this study are those of the World Gold Council. They constitute the spot prices of the XAU gold ticker. That is the most common "Gold exchange rate" and represents the currency code for gold ounces. Prices are quoted in dollars.

The prices of oil and gold will be deflated using the Manufacturer Unit Value of Exports (MUV).

MUV: The Manufacturer Unit Value of Exports (MUV) is a measure of the price of developed country exports of manufactures in U.S. dollar terms. The MUV is a composite index of prices for manufactured exports from the fifteen major developed and industrial economies, valued in U.S. dollars. The countries and relative weights (in parentheses) are: Brazil (2.95%), Canada (0.93%), China (11.79%), France (5.87%), Germany (13.29%), India (1.77%), Italy (6.07%), Japan (16.70%), Mexico (0.93%), South Africa (0.75%), South Korea (10.95%), Spain (2.30%), Thailand (2.51%), United Kingdom (3.50%), and United States (19.68%). It is extracted from the International Monetary Fund (IMF) and will be used here to deflate commodities such as gold and oil. The base year for this indicator is 2005. The reason behind using such a composite as a deflator for commodities instead of the consumer price index (CPI) is that in the middle of the 1990's, the Boskon Commission report argued that the use of the US CPI overstates inflation by almost 1.1 percent. Such an exaggeration had important

implications for long term trends in real commodities prices using CPI as a deflator. CPI being overstated, long-term growth rate would consequently be understated. (Cuddington, J. 2007)

Whereas, the exogenous variables defined as variables independent from states of other variables in the system and determined by variables outside the causal system studied, are the U.S. Dollar Index and the U.S. CPI:

US Dollar Index: The US dollar index is a measure of the value of the United States dollar with regard to a basket of foreign currencies, including: Euro, Japanese Yen, Sterling Pound, Canadian Dollar, Swedish Krona and Swiss Franc. In other words, whenever the US dollar index increases, it follows that the value of US dollar is strengthened compared to the other currencies.

Inflation: We consider inflation rate in USA. It is measured by the Consumer Price Index (CPI) which is an overall price of all goods and services purchased by a typical urban consumer. Seasonal adjustment removes the effects of recurring seasonal influences from many economic series, including consumer prices. The CPI used is seasonally adjusted. The adjustment process quantifies seasonal patterns and then factors them out of the series to permit analysis of non-seasonal price movements. Changing climatic conditions, production cycles, model changeovers, holidays, and sales can cause seasonal variation in prices. For example, oranges can be purchased year-round, but prices are significantly higher in the summer months when the major sources of supply are between harvests.

All the above mentioned variables will be taken in natural logarithm.

3.4 Statistical package

There exist many statistical packages for research on the market. Those mostly used are SPSS, Eviews, MATLAB, JMulTi... However, in this thesis Eviews 5.0is used being among the best fit tools to handle times series.

3.5 Methodology

In order to model the long run relation between the price of gold and the price of oil we estimate a Vector Error Correction model (VEC). We start first by testing the presence of a unit root in the endogenous and exogenous variables using the standard Dickey-Fuller unit root test. Then we test the presence of cointegration between the above mentioned endogenous variables using Johansen cointegration test. Thirdly, we estimate a VEC with exogenous variables, inflation rate in USA and the U.S. Dollar Index. Finally, to test the direction of causality between the price of oil and the price of gold we apply Granger causality test.

3.5.1 Unit Root test

It is common for macro-economic variables to increase over time. These variables may present a deterministic trend or a stochastic trend. The latter type of variables are said to be non-stationary. Such variables have a joint probability distribution that changes over time. This will cause two problems. The first is a statistical problem. In fact, standard errors of the estimated coefficients will be biased. This means that standard tests like Student test or Fisher test used in general to investigate the causal relationship between the variables are no more reliable. Therefore, one should understand that noise leads to imperfect theory and statistical techniques. Regression will seem to have a good fit and have statistically significant

relationship between variables where none is really existent. This problem is called "spurious regression". The second problem is an economic problem. In fact, the effects of a shock i.e. monetary policy shock or depreciation of the exchange rate will not dissipate in the long run, which is unrealistic.

A variable is defined to be strongly stationary when its joint distribution is time invariant. This implies that all cross-sectional moments of the distribution (the mean, the variance …) don't depend on time and that correlations across time do not change.

A time series is said to be weakly stationary if its series exhibit mean reversion and fluctuates around a constant long run mean, the variance of the series is constant, and the value of auto-covariance between two-time periods depends only on the distance or lag between the two time periods and not on the actual time at which the covariance is calculated.

An example of a non-stationary time series(y_t) is the random walk model represented as:

$$y_t = y_{t-1} + \varepsilon_t \qquad (1)$$

Whereε_t is a stationary disturbance white noise term. The series y_t has a constant forecast value, conditional on t, and the variance is increasing over time. The random walk is a difference stationary (DS) series since the first difference of y_t is stationary:

$$y_t - y_{t-1} = \varepsilon_t \qquad (2)$$

A difference stationary series occurs when the shocks do not dissipate with time. Therefore the value of each period's value is that of the previous period value plus the change resulting from the shock. Such variable is represented by equation (1). Taking the first difference of equation (1) the variable becomes stationary and can be written as in equation (2). Moreover, time series may be trend stationary (TS). A trend stationary series can be obtained by detrending it. Whenever one detects the type of stationarity, appropriate course of treatment for the series would be on hand.

The above variable (y_t) is said to be integrated of order one, since it needs to be differentiated once to become stationary. Variables that need to be differentiated n times to become stationary are said to be integrated of order n (Mahadeva, L. & Robinson, P. 2004). In order to test the stationarity of our variables, Dickey-Fuller (DF) and Augmented Dickey-Fuller (ADF) unit root tests will be used. These tests test the null hypothesis that the variable has a unit root (non-stationary) versus the alternative that it is stationary. ADF test proposes three models under the alternative hypothesis. The first includes only a constant, the second only a linear trend, and the third a constant and a trend. The latter one is represented under the alternative hypothesis by one of the following equations:

$$\Delta x_t = \alpha + \beta x_{t-1} + \gamma t + \sum_{i=2}^{p} \delta_i \Delta x_{t-1+1} + \varepsilon_t \quad (4)$$

$$x_t = \alpha + \rho x_{t-1} + \gamma t + \sum_{i=2}^{p} \delta_i \Delta x_{t-1+1} + \varepsilon_t \quad (5)$$

Where α is the constant, t is a linear trend and p is the number of lags. If p is zero, the above model will be the simple DF model. Model one only includes α while model two only includes γt. To decide which model to choose we simply look at the graph of the variable.

The one-tailed null and alternative hypotheses in the ADF test are:

$$H_0: \beta = 0 \text{ or } \rho = 1 \text{ (where } \beta = \rho - 1)$$

$$H_1: \beta \neq 0 \text{ or } \rho \neq 1$$

Series is said to be stationary if the null hypothesis is rejected. We reject the null hypothesis if in absolute value the test statistic is greater than the critical value calculated by Dickey and Fuller. Thus, if:

$\left|t = \frac{\hat{\beta}}{\hat{\sigma}_{\hat{\beta}}}\right| < |C|$, thenwe do not reject the null hypothesis

$\left|t = \frac{\hat{\beta}}{\hat{\sigma}_{\hat{\beta}}}\right| > |C|$, then we reject the null hypothesis

Where C is the corresponding critical value at a certain significance level.

If the variable is not stationary in level we check if it is in first difference by applying ADF test on the first difference. If the first difference is not stationary then we take the 2nd difference and apply again the ADF test and so on.

The size and the power of ADF test are sensitive to the number of lags. Dickey and Fuller tabulated their critical values under the assumption that the residuals in the above equations are not auto correlated. If they are, they suggested including a certain number of lags that eliminates autocorrelation from the residuals. We choose the minimum lags number that eliminates the autocorrelation from the residuals. To do so, we apply the below described Ljung-Box test.

3.5.2 Ljung-Box Test

The Ljung–Box test tests whether a group of autocorrelations of a time series is different from zero or not. Instead of testing randomness at each distinct lag, it tests the "overall" randomness based on a number of lags, and is therefore a portmanteau test. Thus, the Ljung–Box test can be defined as follows.

H_0: The data are independently distributed. Thus, all autocorrelations are null.

$$\boldsymbol{\rho_1 = \rho_2 = \cdots \rho_k = 0}$$

H_1: The data are not independently distributed. At least one of the autocorrelations is different from zero.

$$\boldsymbol{\exists\ \rho_i\ /\ i \in \{1, \ldots, 12\} \neq 0}$$

The test statistic is given by:

$$\boldsymbol{Q = T(T+2)\sum_{k=1}^{h} \frac{\rho_k^2}{T-k}} \tag{6}$$

Where $\boldsymbol{T}$ is the sample size, $\boldsymbol{\rho_k^2}$ is the sample autocorrelation at lag $\boldsymbol{k}$, and $\boldsymbol{h}$ is the number of lags being tested, here $h=12$. Twelve lags are chosen because the data is monthly and autocorrelation is not allowed till one year. For significance level α, we reject H_0 if:

$$\boldsymbol{Q > \chi^2_{1-\alpha,h}} \tag{7}$$

Where $\chi^2_{1-\alpha,h}$ is the α-quantile of the chi-squared distribution with h degrees of freedom.

3.5.3 Cointegration test

The financial theory suggests that in the long run, some pairs of financial time-series data are projected to move together. Short run deviations are claimed to be brought back to equilibrium because of, for example, investors' preferences and taste, government regulations and market forces. In order to investigate whether our variables present a short and/or a long run relation, we test the presence of cointegration relation between them. Testing cointegration is a powerful exploration tool for common trends in multivariate time series. It provides a sound tactic for modeling both long run and short run dynamics in a system. Cointegration is a modeling method that integrates non-stationary series with both long-term relationships and short-term dynamics. In order to examine whether two series are cointegrated, the former should be non-stationary and integrated of order 1. (Magiora, D. &Skerman, R. 2009)

To test for cointegration between gold, and oil, the Johansen cointegration test is used. This test is a maximum likelihood technique that verifies the number of cointegrating vectors in a non-stationary time series Vector Autoregression (VAR) represented as follows:

(8)

$$\boldsymbol{y_t = A_1 y_{t-1} + \cdots + A_p y_{t-p} + B\, x_t + \epsilon_t}$$

Where y_t is a vector of non-stationary I (1) variables, that is in this case LOGOIL_REAL and LOGGOLD_REAL. x_t is a d-vector of deterministic and/or exogenous variables, here LOGUS-DOLLAR_INDEX and LOGUS_CPI and ε_t is a vector of innovations. p is the minimum number of lags that eliminates autocorrelation from the VAR.

$$\boldsymbol{A_i = \begin{pmatrix} a^i_{1\,1} & a^i_{1\,2} \\ a^i_{2\,1} & a^i_{2\,2} \end{pmatrix}} \qquad \text{for } \boldsymbol{i = 1 \rightarrow p}$$

And $\boldsymbol{B_i} = \begin{pmatrix} b_{1\,1} & b_{1\,2} \\ b_{2\,1} & b_{2\,2} \end{pmatrix}$ are matrices of coefficients to be estimated.

The VAR model can then be rewritten as a VEC model:

$$\Delta y_t = \Pi y_{t-1} + \sum_{i=1}^{p-1} \Gamma_i \Delta y_{t-1} + B\, x_t + \epsilon_t \tag{9}$$

Where:

$$\Pi = \sum_{i=1}^{p} A_i - I \qquad\qquad \Gamma_i = -\sum_{j=i+1}^{p} A_j \tag{10}$$

Johansen (1991) identifies two distinct test statistics for cointegration: the Trace test and the Maximum Eigenvalue test.

The Trace test is a combined test that tests the null hypothesis of no cointegration against the alternative hypothesis of cointegration (Brooks, 2008):

$$\mathbf{H_0}: r = 0$$

$$\mathbf{H_1}: r > 0$$

The test statistic is given by:

$$LR_{tr}(r; k) = -T \sum_{i=r+1}^{k} log\,(1 - \lambda_i) \tag{11}$$

H_0 will be rejected whenever the test statistic is bigger than the critical value given by Johanson.

The Maximum Eigenvalue test conducts experiments on each eigenvalue separately. It tests the null hypothesis that the number of cointegrating vectors is equal to r against the alternative of $r + 1$cointegrating vectors. (Brooks, 2008)

The test statistic is given by:

$$LR_{max}(r; r+1) = -T\,log\,(1-\lambda_{r+1}) \qquad (12)$$

r= number of cointegrating vectors under the null

λ_r = estimated i^{th} ordered eigenvalue

Finally, a significantly non-zero eigenvalue leads to a rejection of the null hypothesis indicating a significant cointegrating vector. Then, H_0 will be rejected whenever the test statistic is bigger than the critical value given by Johanson's tables.

3.5.4 Granger causality test

The Granger causality test offers information regarding causal relations between the studied variables. It indicates whether one variable is helpful in forecasting another. In other words, the present worth of one variable is a reason behind previous values of different variables. For example, "crude oil price is said to Granger-cause gold prices if gold prices can be better predicted using the histories of both crude oil prices and gold prices than it can by using the history of gold prices alone". In order to perform the test, variables should be stationary. The number of lags involved is usually selected using the number of lags used to perform a Vector Error Correction (VEC) test.

Subsequently, in order to complete this test one retains the following two null hypotheses concerning equation (8).

$$\mathbf{H_0}: a_{1\,2}^{1} = a_{1\,2}^{2} = \cdots = a_{1\,2}^{i} = 0 \ \textbf{for} \ i = 1 \rightarrow p$$

Whenever H_o is not rejected, it is possible to conclude that gold prices do not Granger cause oil prices.

And:

$$\mathbf{H_0}: a_{2\,1}^{1} = a_{2\,2}^{2} = \cdots = a_{2\,2}^{i} = 0 \ \textbf{for} \ i = 1 \rightarrow p$$

If ever this above H_0 is not rejected, it is possible to conclude that oil prices do not Granger cause Gold prices

3.5 Conclusion

After having covered the literature framework on this topic, two hypotheses are on hand. The first one is to test whether crude oil prices affect gold prices and the second will be whether these two variables are not directly related, they are simply affected by common factors. Later on, the data used is individually defined along with its source of extraction, the instrumentation package and procedures to be used for empirically testing the hypotheses. The first step will be to define whether the time series are stationary by performing the DF and ADF unit root tests. Later on, those series are tested for cointegration using the Johansen test. If ever the series are found to be non-stationary and cointegrated, a vector error correction model is to be implemented followed by a Granger causality test. Ready for testing, the results will be discussed in the coming chapter.

Chapter 4

Findings

4.1 Introduction

In chapter three, we identified and explained the methodology that will be used in this thesis to test the three hypotheses set in chapter one. Subsequently, in this chapter the estimation results will be discussed. In the second section, brief descriptive statistics and primary correlation matrix will be presented. In the third section the results of Dickey-Fuller unit root test, Johansen cointegration, the VEC and Granger causality test will be detailed and commented. The last section stands for the conclusion.

4.2 Descriptive statistics

The descriptive statistics in table (1) show that the means of the four variables – LOGGOLD, LOGOIL, LOGUS_DOLLAR_INDEX, and LOGUS_CPI– are respectively 6.22, 3.61, 4.5, and 5.21. Their medians are respectively 5.96, 3.42, 4.47 and 5.2. Moreover, the coefficient of standard deviation shows that LOGOIL has the highest volatility, followed by LOGGOLD and finally LOGUS_CPI and LOGUS_DOLLAR_INDEX.

	LOGUS_CPI	LOGUS_DOLLAR_INDEX	LOGGOLD	LOGOIL
Mean	5.211	4.501	6.229	3.611
Median	5.207	4.478	5.960	3.419
Maximum	5.450	4.789	7.510	4.942
Minimum	4.958	4.274	5.544	2.418
Std. Dev.	0.145	0.124	0.589	0.668
Observations	243	243	243	243

Table 1: Summary Statistics

The correlation matrix in table (2) shows a strong positive relation between LOGGOLD_REAL and LOGOIL_REAL (0.789), LOGGOLD_REAL and LOGUS_CPI (0.838), LOGOIL_REAL and LOGUS_CPI (0.937). This is expected since oil is fueling up inflation level and hence CPI. It also illustrates a strong negative relation between LOGUS_DOLLAR_INDEX and LOGGOLD_REAL (-0.73). This could be due to the fact that gold is the ultimate safe haven for investors especially when US dollar's value declines. Moreover, table (2) indicates a negative relationship between LOGUS_DOLLAR_INDEX with both LOGOIL_REAL and LOGUS_CPI. These are respectively (-0.558) and (-0.535). The reason could be because both commodities are used as hedging tools for investors.

	LOGGOLD_REAL	LOGOIL_REAL	LOGUS_CPI	LOGUS_DOLLAR_INDEX
LOGGOLD_REAL	1.000	0.789	0.838	-0.730
LOGOIL_REAL	0.789	1.000	0.937	-0.558
LOGUS_CPI	0.838	0.937	1.000	-0.535
LOGUS_DOLLAR_INDEX	-0.730	-0.558	-0.535	1.000

Table 2: Correlation Matrix

4.3 Main results

4.3.1 Unit root test

Before estimating a Vector Error Correction model (VEC), we test the stationarity of LOGGOLD, LOGOIL, LOGUS_DOLLAR_INDEX and LOGUS_CPI. These variables should be stationary in order to conduct any inferential statistics and have a mean reverting series in the long run.

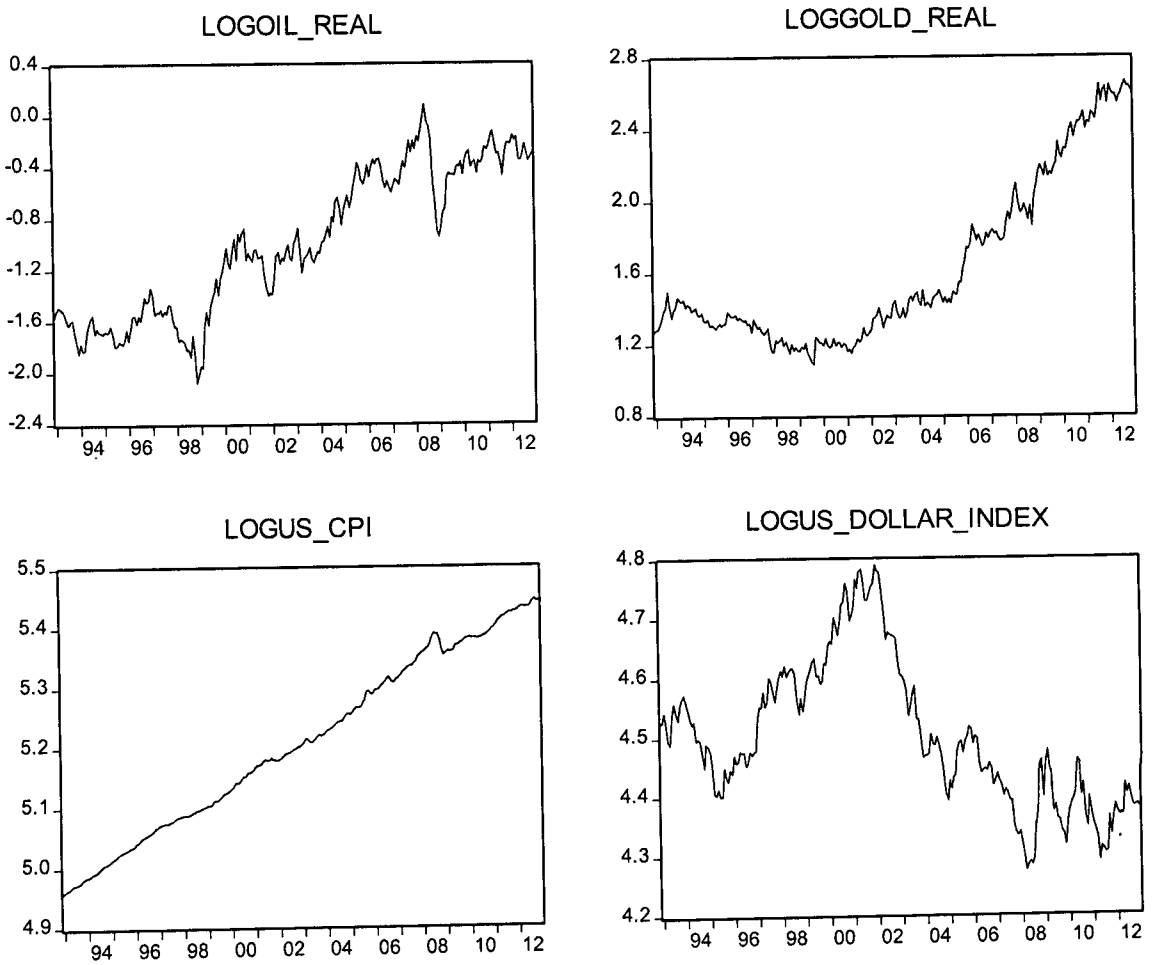

Figure 10: Line chart for LOGGOLG, LOGOIL and LOGUS_DOLLAR_INDEX

To test for stationarity, we use Dickey-Fuller (DF). As mentioned in chapter three, DF test allows three models under the alternative hypothesis of stationarity. The choice of the model depends on the presence or absence of a linear trend. Figure (10) shows that gold, oil and the U.S. CPI have a deterministic linear trend (intercept and trend).Whereas the U.S. Dollar index has only an intercept.

Moreover, the results of Dicker Fuller test presented in Table (3) show that all the selected variables are not stationary at 1%, 5% and 10% significance level except for

LOGOIL_REAL which is stationary at 5% and 10% significance level but not at 1% significance level.

	ADF TEST	Critical Values 1%	Critical Values 5%	Critical Values 10%	LAGS
LOGOIL_REAL	-3.966**	-3.997	-3.429	-3.138	3
LOGGOLD_REAL	-1.139	-3.997	-3.429	-3.138	1
LOGUS_DOLLAR_INDEX	-1.365	-3.458	-2.873	-2.573	1
LOGUS_CPI	-2.638	-3.997	-3.429	-3.138	3

NB: *,**,*** denote respectively the rejection of the null hypothesis of unit root at 1%, 5%, and 10%

Table 3: Dicker- Fuller test results

The number of lags chosen in the DF test is the minimum number that eliminates autocorrelation from the residuals till order 12. The order of autocorrelation is arbitrary chosen. In fact, since data is monthly we do not allow autocorrelation in the residuals till one year. Ljung-Box test is used to test the autocorrelation of the residuals at 5% significance level. Therefore, DF test fails to reject the null hypothesis of unit root at all three reported significance levels for LOGGOLD_REAL, LOGUS_DOLLAR_INDEX and LOGUS_CPI. Thus, we conclude that the latter three variables have a unit root and therefore are non-stationary series. LOGOIL_REAL is not stationary at 1% significance level.

4.3.2 Cointegration test

As discussed earlier, crude oil and gold prices have a tendency to move together. Thus, a cointegration relationship is expected. We use Johansen cointegration test in order to test the presence of a cointegration relation between these two variables. The chosen number of lags in the VEC is the one that eliminates autocorrelation from the residuals of the corresponding VAR minus one lag. The endogenous variables in the VAR are LOGGOLD_REAL and LOGOIL_REAL, and two exogenous variables are

added, LOGUS_DOLLAR and LOGUS_CPI[1].All the variables in the VAR are taken in their first difference. We use the LM Portmanteau test to test the autocorrelation in the VAR's residuals. The minimum lags number that eliminates autocorrelation from the VAR's residuals at 5% significance level is 4.

The VEC model is a restricted VAR intended to be used with nonstationary series that are cointegrated. The cointegration relation in the VEC accounts for a long run relation between the endogenous variables. The VEC also allows short term correction dynamics. The cointegration term is the error correction term since its deviation from long-run equilibrium is adjusted regularly via a series of fractional short-run adjustments. The number of lags to be used for this VEC model is that of the VAR model minus one lag. That is 4-1=3 lags. Moreover, endogenous variables –LOGGOLD_REAL and LOGOIL_REAL– are taken in level unlike the VAR. While the exogenous variables –LOGUS_DOLLAR_INDEX and LOGUS_CPI– are taken in their first difference. Below are the results of the VEC model:

$$
\begin{aligned}
&D(LOGOIL\_REAL) \\
&\quad = A(1,1) * (B(1,1) * LOGOIL\_REAL(-1) + B(1,2) * LOGGOLD\_REAL(-1) \\
&\quad + B(1,3) * @TREND(92M12) + B(1,4)) + C(1,1) * D(LOGOIL\_REAL(-1)) \\
&\quad + C(1,2) * D(LOGOIL\_REAL(-2)) + C(1,3) * D(LOGOIL\_REAL(-3)) \\
&\quad + C(1,4) * D(LOGGOLD\_REAL(-1)) + C(1,5) * D(LOGGOLD\_REAL(-2)) \\
&\quad + C(1,6) * D(LOGGOLD\_REAL(-3)) + C(1,7) + C(1,8) * D(LOGUS\_CPI) \\
&\quad + C(1,9) * D(LOGUS\_DOLLAR\_INDEX)
\end{aligned}
$$

[1] Before deciding on the endogenous and exogenous variables to be tested, many combinations were taken into combination and tested. However, the Johanson test shows no cointegration in the long term except when using those gold and oil prices as endogenous variables and the U.S. Dollar index and the U.S. CPI as exogenous variables. Thus papers not taking into consideration these variables as such may lead to none robust results.

$$D(LOGGOLD\_REAL) = A(2,1) * (B(1,1) * LOGOIL\_REAL(-1) + B(1,2) * LOGGOLD\_REAL(-1) + B(1,3) * @TREND(92M12) + B(1,4)) + C(2,1) * D(LOGOIL\_REAL(-1)) + C(2,2) * D(LOGOIL\_REAL(-2)) + C(2,3) * D(LOGOIL\_REAL(-3)) + C(2,4) * D(LOGGOLD\_REAL(-1)) + C(2,5) * D(LOGGOLD\_REAL(-2)) + C(2,6) * D(LOGGOLD\_REAL(-3)) + C(2,7) + C(2,8) * D(LOGUS\_CPI) + C(2,9) * D(LOGUS\_DOLLAR\_INDEX)$$

Based on the VEC model, the results of the Johansen cointegration test are shown in table (4) below.

Selected (0.05 level*) Number of Cointegrating Relations by Model					
Data Trend:	None	None	Linear	Linear	Quadratic
Test Type	No Intercept	Intercept	Intercept	Intercept	Intercept
	No Trend	No Trend	No Trend	Trend	Trend
Column number	1	2	3	4	5
Trace	0	0	0	1	1
Max-Eig	0	1	0	1	1

*Critical values based on MacKinnon-Haug-Michelis (1999)

Table 4: Johansen cointegration test summary

As explained in chapter 3, the Johansen cointegration test proposes five models. The results of the test are the following:

- Whenever considering no intercept and no trend in the cointegration equation, both Trace and Max-Eig tests show no cointegration in the long term (column 1).
- If only an intercept is included in the cointegration equation, Trace test concludes no cointegration relation unlike the Max-Eig value that shows the presence of one cointegration relation (column 2).

- Whenever using linear data trend with no trend and an intercept, both tests show no long run cointegration (column 3).
- If the data is linear and have both an intercept and a trend, both tests confirm long term cointegration relation (column 4).
- Finally, quadric data, with both an intercept and a trend, results in a cointegration relation in the long run based on both tests (column 5).

Variables presented in figure (10) show the presence of a linear trend. Thus, it seems logic to consider the presence of a linear trend in the cointegration relation and the data. Based on the results from table (4) we can then conclude that there is a cointegration relation between gold and oil whenever the US dollar index and the US CPI are considered as exogenous variables.

4.3.3 Granger Causality test

Crude oil price is said to Granger-cause gold price if crude oil price helps in the prediction of gold price. Once the test was performed on the two series using two lags, the results returned as shown in table (5).

Dependent variable: LOGOIL_REAL			
	Chi-sq	df	Prob.
LOGGOLD_REAL	4.23954	2	0.120
Dependent variable: LOGGOLD_REAL			
	Chi-sq	df	Prob.
LOGOIL_REAL	7.75813	2	0.021

Table 5: Granger causality test

The results in table (5) show that LOGGOLD_REAL, doesn't Granger cause LOGOIL_REAL. In fact, the *p*-value of the test is 12% which is greater than 1%, 5% and 10%. Thus, we do not reject the null hypothesis that the lags of LOGGOLD_REAL

are jointly not significant in the first equation of the VEC with LOGOIL_REAL the dependent variable. However, LOGOIL_REAL Granger causes LOGGOLD_REAL. The *p*-value of the test is 2.1% which is less than the significance level of 1%, 5% and 10% significance level. Thus, we reject the null hypothesis that the lags of LOGOIL_REAL are jointly not significant in the second equation of the VEC with the LOGGOLD_REAL dependent variable.

4.4 Conclusion

In this chapter, empirical testing has been performed on gold prices and oil prices used as endogenous variables, and the U.S. Dollar index and the U.S. CPI used as exogenous variables. All four time series were collected over a period of 20 years, covering periods of various economical events. The findings show that over the mentioned period, all 4 time series are non- stationary and have a unit- root. The presence of a linear data with a trend for these series proves the existence of a long term cointegration relation.

It is important to note that after several testing, this long term relation is found among variables only when gold and oil prices are used as endogenous variables and the U.S. Dollar index and the U.S. CPI as exogenous variables. Finally, having found that the variables all have a unit root and a cointegration relationship in the long run, a Granger causality test was performed. The results showed a causality relation running from oil prices to gold prices; but not the other way around. Thus, it is possible to conclude that oil prices are not affected by gold prices, only gold prices can be anticipated through oil price changes.

Chapter 5

Conclusions and Recommendations

5.1 Introduction

This thesis examines the price relation among crude oil and gold by studying the indirect effect of oil price on gold price through the inflation channel and studying their interactions with the US dollar index. It is then comprised of two types of analysis: literature and empirical. In the first part, the literature for both gold and crude oil was discussed and a link was observed among them. Next, moving to the empirical part, previous studies have been reviewed where three main hypotheses were assumed. These are the following. First, oil prices do affect gold prices through inflation channels and/or revenue channels. Second, oil and gold were found not to be correlated. They only depend on macro-economic variables. Third, gold and oil were found to have a negative relation, oil being one of the costs incurred in gold mining and its price increase would affect gold prices negatively.

No consensus being found, this thesis's tried to fill the existing gap. The aim is to support the literature and provide proof of the observed link among those two commodities. It would be than possible to empirically answer the main issue on hand: how are crude oil prices and gold prices correlated?

In this chapter, the main findings will be summarized; the managerial implications, the limitations and recommendations will be also discussed.

5.2 Main findings

Throughout this thesis, relationship between crude oil prices and gold prices was expressed through literature review and empirical testing. In chapter two, positive correlation was spotted among crude prices, gold prices, GDP and the U.S. CPI. However an inverse relation was found between these two commodities, interest rates and the U.S. Dollar index.

Gold prices, oil prices, the U.S. Dollar index and the U.S. CPI figures were first tested in chapter four for the presence of a unit root. Cointegration analysis and Granger causality testing were performed on a monthly basis for the period of twenty years. First, all four tested variables were found to be non stationary; in other words, any shock affecting each time series separately have a permanent effect which doesn't decompose. Second, the Johanson cointegration test reveals long term relationship between crude oil prices and gold prices. Both the U.S. Dollar index and the U.S. CPI are used as exogenous variables. That confirms that after market fluctuations, both series return to long-term equilibrium. Finally, the Granger causality test revealed causal links between gold and oil price levels. It showed that there exists a unidirectional causality relationship running from crude oil prices to gold prices. Chapter two found such relation to be caused by inflation and revenue channels. It means that, in the long-run, an increasing oil price stimulates higher inflation which, in turn, fortifies the demand for gold. Such a demand will thereafter push gold prices up. Such a shift toward gold investments in high inflation periods was found in chapter two to be primarily caused by the fact that gold plays the role of a "safe haven". Alternately, increased crude oil prices cause an increased inflow of funds into oil producing companies. Those proceeds are likely to be invested in gold, being an important part of every investor's portfolio. However, the Granger causality test showed that even though crude prices helped determine gold prices, the opposite was not true. Gold prices were found not to Granger cause oil prices.

5.3 Limitation of the research

This work generates important findings with regard to the relationship between crude oil and gold prices. However, it is crucial to confirm the presence of certain limitations for this study. The main limitations concern first the collection of data. The testing procedure could not involve GDP and interest rates. This is mainly because GDP is not monthly available and the use of its quarterly figures would result in a non-representative sample of around 80 observations. As for interest rate, choosing the monthly U.S. treasury bills interest rate is not fairly representative of the U.S. interest rate where larger scales should be employed. Second, taking larger samples that would appropriately account for these variables by keeping sample size representative was not an option due to the time constraint.

5.4 Managerial implications

This thesis has yielded both managerial insights for investors and estimation tools for speculators. Therefore, investors are able to properly manage their portfolios while considering crude oil, gold, and the U.S. Dollar index. At first, as it comes to diversification, it is possible to deduce from this work a negative beta, or systematic risk relation between crude oil and gold on one hand, and the U.S. Dollar on the other hand. Second, it is possible to estimate crude oil and gold price movements from any information regarding future GDP, inflation, and interest rates. For example, an expected decrease in interest rates would encourage portfolio managers to invest in gold and crude oil in order to compensate on such a downturn in interest bearing securities. That being noted, speculators will have a more efficient speculative tool for both oil and gold the moment any estimate is released on the other three indicators, GDP, CPI, and the U.S. treasury bills interest rates. Moreover, this work is a major breakthrough for, not only those who uses gold as an investment asset, but also for those who uses gold as consumption good. Whenever the course of correlation is established, gold industry participants can better anticipate when to buy its inventory of gold and when to sell; in order to maximize their profits.

5.5 Recommendations

The number of studies on oil and gold prices relationships is to some degree narrow. This is mainly because the importance of their correlation have surged recently when their impact have affected the economy. This offers opportunities for additional research in the area. For instance, taking into consideration the limitations of the study, further research can be conducted to be able to efficiently report the effect of the GDP and interest rates on both crude oil and gold prices. Moreover, further studies can be conducted to evaluate the volatility, risk and spillover effects between both gold and crude oil markets and other markets such as the precious metals market and the energy market. Finally, once the course of correlation have been identified in this thesis, other work can emphasis on quantifying this relationship in order to be better predicted in actual figures.

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