Oil, Gold, US dollar and Stock market interdependencies: A global analytical insight

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Abstract
This paper takes a global perspective in examining relationships among oil, gold, US dollar and stock prices, using simultaneous equations system to identify direct and indirect linkages for the period spanning from January 1995 to October 2015. Results show significant interactions between the all parties. Indeed, we found negative relation between oil and stock prices but oil price is significantly and positively affected by stock markets, gold and USD. Oil price is also affected by oil future prices and by Chinese oil gross imports. Gold price is concerned by changes in oil, USD and stock market prices but slightly depend on US oil imports and corporate default premium. The US dollar is negatively affected by stock market and significantly by oil and gold prices and also by US consumer price index. Indirect effects always exist which confirm the presence of global interdependencies and involve the financialization process of commodity markets.

Key words: Oil price, gold price, trade weighted exchange rate, stock market, simultaneous equations.

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1. Introduction

The sustained rise in interdependence of global markets alongside with the international financial integration have accelerated the financialization process of commodity markets (Tang and Xiong, 2012) and led stock and foreign exchange markets to be more sensitive to commodity prices.

Moreover, the unusual breaking events and the shortage of liquid financial assets make investors questioning their worldview about the risk of equity investing and triggered a particular interest in precious metals and energy markets (Caballero et al., 2008). Commodity markets have then attracted international investor's attention not only as "safe haven" to hedge against economic and financial risk but also as a alternative investment with greater sense of certainty during periods of financial market instability (Baur and McDermott, 2010). Oil and gold are the most widely traded commodities and become among the most popular economic indicators.

In the presence of financialization process of commodity markets, oil price, gold price, US dollar, and stock prices have acquired further diversification properties and have become sharing similar statistical properties as well as other common characteristics (Ciner, 2001; Vivian and Wohar, 2012; Chkili et al., 2014). They are significantly correlated with each other and with the outlook of the global business cycle. In that framework, the price dynamics of all these assets, as determined in the free global markets, are important indicator of collective expectations on the future state of the world economy and investment horizons. What investors feel the future might be reflected in the information contents of prices of these assets.

We motivate this research paper by the substantial implications of the price movements of the present assets and commodities on real economy, financial sectors as well as on financial

markets. Therefore, understanding their co-movement prices has great significance for investor expectations, policy makers and portfolio managers.

The aim of this study is to highlight the interdependent relationships between the all markets. We try to meet a global analytical insight while pointing to potentially important direct and indirect interactions. We first discuss theoretically the causal bilateral relationships directly and through the effect of other asset prices and then, empirically, the all-party interdependencies through a simultaneous analysis. We develop the study in a global framework and make use of international data. Indeed, we employ Brent crude oil price, international gold prices, broad trade weighted US dollar index and the world stock market return index as principal data. Other representative data associated with the expected world economic state, monetary policy, financialization of oil markets, corporate default risk have been employed to control for exogenous and indirect effects.

The theoretical possibility of both direct and indirect channels calls for a simultaneous equation methodology. The empirical methodology used to meet aims of the study is then a simultaneous equations approach put forward by Imbs (2004) which allows studying the magnitude of all theses linkages and grants one the possibility of more adequately investigating the complex system of interactions among oil, gold, foreign exchange and stock prices. This approach makes it possible to rely on potential links via other indirect effects. We then specify an equation to each endogenous variable which includes others endogenous variables as exogenous and other exogenous variables to captures indirect effects. Fundamentally, we attempt to answer the following questions: to what extent oil, gold, foreign exchange and stock market are interdependent? and what nature and direction of effects portray their interdependencies?

Main founded results show significant interactions between oil price, gold price, US dollar and stock prices. Indeed, we found negative relationships among oil price and stock market

but oil price is significantly affected by stock markets, gold and trade weighted USD exchange rate. Oil price is also affected by oil future prices as well as by Chinese oil gross imports. Gold prices are concerned by changes in oil, USD and stock markets but slightly depend on US oil imports and default premium. The trade weighted USD exchange rate is significantly affected by oil price, gold price and stock market prices. The broad US dollar exchange rate is also negatively affected by US consumer price index. We note that indirect effects always exist which confirm the presence of global interdependencies and financialization process of commodity markets. We explain the obtained results by the increased use of both oil and gold as financial assets either for speculation or for hedging, which intensified the link between the all markets and thus confirm that the performance of these markets become dependent between each other.

This article differs from similar previous studies in several aspects. First, most of research papers focus on bilateral linkages such as oil versus stock markets (Jones and Kaul, 1996; Sadorsky, 1999; Aloui and jammazi, 2009; Arouri et al., 2012; Mollick and Assefa, 2013; …), oil price versus gold price (Zhang and Wei, 2010; Ewing and Malik, 2013; Bampinas and Panagiotidis, 2015), gold prices versus stock markets (Sumner et al., 2010; Gaur and Bansal, 2010; and Le and Chang, 2012), oil price versus exchange rates (Basher et al., 2012) and other on trilateral linkages such as oil price, exchange rates and stock prices (Sekmen, 2011 ; Olugbenga, 2012; Fratzscher et al., 2014), and gold, foreign exchange and stock market (Shahram et al., 2015). We implement our investigation on the four markets simultaneously. Second, we develop our study in a global framework and use international data. Indeed, we employ Brent oil price, gold price, broad trade weighted US dollar index and the international stock market index. This global analysis allow avoiding country specific effects that may be inherent to domestic sectoral or industrial specialization, foreign exchange regimes, PPP or inflationary economies, financial development, domestic market sizes etc. Third, the

simultaneous equations approach makes it possible to answers to many questions associated with bilateral interactions (6 bilateral relationships) as well as it allows to control for direct and indirect effects in so far as the four markets represent different economic sectors, different patterns of specialization, national monetary policies, and miscellaneous stock markets microstructures and informational efficiency. Finally, the global framework of this study provides useful insights for investment, managerial and governmental executive purposes.

The remainder of the paper is organized as follows. The second section presents a glance at the existing literature. The third section presents the used data, a theoretical analysis and declares hypothesis of the study. The fourth section outlines the empirical methodology. The fifth section discusses empirical results and the final section concludes the study.

2. A glance at the existing literature

Relationships between financial and commodity markets have been documented in a sizeable literature. We present and discuss here bilateral relationships while interest in multilateral interactions in the empirical results.

Oil price vs. US dollar exchange rate

The relation between oil price and exchange rates has been initially documented by Golub (1983) and Krugman (1983a) who put forth compelling arguments as to why movements in oil price should affect exchange rates. Golub reasons that since oil price is denominated in USD, an increase in oil price will lead to an increase in demand for US dollars. However, Krugman's (1983a) analysis is based on the relationship among portfolio investment preferences of oil exporters and movements in exchange rates. Indeed, rising oil price will increase portfolio investment possibilities of oil exporters. In Krugman's (1983a) analysis, exchange rate movements are determined primarily by current account movements. If rising oil price lead to a country's current account deterioration, then exchange rates will fall. More

recent evidence on this effect can be found in Bodenstein et al. (2011), Jean-Pierre Allegret et al., (2014), amongst others.

Sadorsky (2000) found that changes in exchange rates impact oil price. Zhang et al., (2008) observed that the influence of the USD on international oil price is significant in the long run, but is limited in short run. Akram (2009) also found that a weaker dollar leads to higher commodity prices. More recently, Fratzscher et al. (2014), found bidirectional causality between the USD and oil price since the early 2000s. Moreover, both oil price and the USD are significantly affected by changes in stock market returns and risk. Indeed, a 10% increase in the price of oil leads to a depreciation of the US dollar effective exchange rate by 0.28% on impact, whilst a weakening of the US dollar by 1% causes oil price to rise by 0.73%. We find that oil price as well as the US dollar exchange rate also responds significantly to other asset price shocks. Specifically, a 1% positive stock market shock increases oil price by 0.7%. The authors note that oil price did not react to changes in financial assets before 2001. This fact provides evidence that the increased use of oil as a financial asset, over the past decade, intensified the link between oil and other assets.

There is a sizeable difference in the strength of transmission between direct and indirect channels. For instance, they find no direct effect of equity market shocks on oil price, but a sizeable and significant overall effect via shocks on interest rates and risk. Similarly, the overall effects of shocks on both oil price and the US dollar are either stronger than the direct effects. This result is important as it suggests that the transmission of shocks on financial markets to and from oil price is not uni-directional and limited to individual asset prices, but that the transmission process is complex and occurs often indirectly via third asset markets.

Oil price versus stock prices

The literature includes various studies that confirm the interdependency between oil price movements and stock prices. For instance, Basher and Sadorsky (2006) reported strong

evidence that oil price risk impacts stock returns on emerging markets. Malik and Hammoudeh (2007), used a multivariate GARCH model for the period spanning from 1994 to 2001, and found that Gulf stock markets receive volatility from oil markets but, only in the case of Saudi Arabia, the volatility spillover takes delivery from the Saudi stock market to oil market underlining the major role that Saudi Arabia plays in the global oil market. Miller and Ratti (2009), used a VECM with additional regressors for the period 1971 – 2008, and observed that stock market respond negatively to oil shocks in the long run, but this negative relationship disintegrated after September 1999. Their results support the existence of structural breaks in this relationship. Oberndorfer (2009), interested in the period 2002 – 2007, using both ARCH and GARCH models and found that rises in oil price effect negatively European stock returns. Basher et al. (2012) used a structural vector autoregression on monthly data for the period 1988 – 2008, and found that positive oil price shocks tend to depress stock prices on emerging market and USD exchange rates in the short run. Janabi et al. (2010) used daily dollar-based stock market indexes to explore whether the GCC equity markets are informationally efficient with regard to oil and gold price shocks during the period 2006 – 2008. The authors found that GCC equity markets are informationally efficient with regard to those commodities. Masih et al. (2011), used a VECM for the period spanning from 1998 to 2005, and observed that oil price shocks have two different negative effects on firm profitability. First, they have a direct negative effect because they increase production costs. And secondly, they have an indirect negative effect because investors suppose declines in profit margins of firms and make decisions that affect stock market dynamics.

More recently, Mollick and Assefa (2013), interested in the relationship between US stock market returns and oil price for the period 1999 – 2011, using GARCH and DCCGARCH models and observed that, prior to the financial crisis, stock returns are slightly (negatively)

affected by oil price and by the USD/Euro. However, for the subsample of mid-2009 onwards, stock returns are positively affected by oil price and a weaker USD/Euro.

Results on the relationship between oil price and stock prices are then mixed in so far as most of the research papers have been conducted using either developed markets or emerging markets stock prices. Oil price dynamics are likely to depend upon oil demands. In fact, the demand for oil is growing slowly or hardly at all in most developed economies, but is rapidly increasing in emerging economies. It depends on the pace of economic growth in national economies as well as on specialization and domestic economic structures. On balance, these studies confirm the evidence that changes in oil price have an effect on stock prices.

Oil price versus gold price

Melvin and Sultan (1990) contend that both changes in oil price and political unrests are significant determinants of gold prices volatility. Narayan et al. (2010) interested in the long-run relationship between gold and oil spot and future prices of different maturities through the inflation channel and observed bidirectional causality in so far as oil and gold price dynamics can predict each other. Zhang and Wei (2010) tested linear and nonlinear relationships (in the sense of Hiemstra and Jones, 1994) between oil and gold markets for the period spanning from January 2000 to March 2008, and observed linear interaction between them and significant unilateral linear Granger causality running from oil to gold.

In the framework of the influencing common factors, Tang and Xiong (2012) state that as a result of the financialization process, futures prices of non energy commodities become increasingly correlated with oil after 2004. This trend has been triggered by the sub-prime crisis. Zhang and Wei (2010) analyzed the cointegration relationship and causality between gold and oil price. The authors found that there are consistent trends between oil price and gold price with significant positive correlation during the sampling period 2000 – 2008. They observed in advance that oil price changes linearly Granger cause volatility of gold price.

Zhang and Wei (2010) bring evidence of high correlations between US dollar and the prices of oil and gold and of Granger causality running from US dollar index to price changes of both commodities.

Reboredo (2013) analyzed the oil-gold dependence structure using copula approach for the period spanning from January 2000 to September 2011, and found positive and significant relationship between them suggesting that gold cannot hedge against oil price volatility. The author observed also a tail independence indicating that gold can perform as a safe haven during turbulent periods of oil market. Wang and Chueh (2013) found positive interaction between gold and oil price for the period 1989 – 2007. Le and Chang (2012) investigate the dynamics between oil price shocks and gold market returns for the period May 1994 to April 2011, using a structural vector autoregressive approach and found that oil price fluctuations are significantly, positively and contemporaneously transmitted to real gold returns. The authors state that oil price fluctuations can help predict gold price dynamics.

More recently, Bampinas and Panagiotidis (2015) examined the causal relationship between crude oil and gold spot prices before and after the recent financial crisis via dynamic bootstrap causality analysis. They found that, in the pre-crisis period, causality is linear and unidirectional and running from oil to gold. In the post-crisis period, they found bidirectional nonlinear causality relationship. The authors conclude that volatility spillover transpires as source of nonlinearity during this period. Investors' decisions and portfolio rebalancing could also act as channels to spillover shocks from other markets and across different commodities (Kyle and Xiong, 2001).

Gold price versus stock market prices

Sumner et al. (2010), Gaur and Bansal (2010) confirmed that, in periods of crisis, falling stock market results always in rising gold prices. Yahyazadehfar and Babaie (2012), and Le and Chang (2012) found significant relationship between stock market prices and gold prices

and state that stock market is a reason for increasing gold rate. Gilmore et al. (2009), used daily time series for the sampling period 1996 – 2007, and found that stock market index was linked with gold mining companies' price index in the long-run and that both variables influence each other in the short-run. Using variance autoregression model and Johansen-Joselius cointegration test on monthly data from March 2001 to April 2011, Yahyazadehfar and Babaie (2012) confirmed that gold price can greatly affect stock prices on Teheran Stock Exchange. The estimated long-run relationship shows that there is a negative relationship between gold and stock prices. Smith (2001) studied the relationship between gold price and stock price indices for the United States over the period 1991 – 2001, using cointegration and Granger causality tests. The author found neither cointegration involving the two variables nor long-run equilibrium and the series do not share a common stochastic trend. Only short-run relationships have been found evident.

There is apparent evidence that in turbulent periods with economic uncertainty, as equity prices fall gold price rises and attention focuses on gold as a safe haven.

US dollar versus Stock market prices

As about the relationship between stock market and foreign exchanges, the existing literature endows with paradoxical reasoning. Traditional approach (at microeconomic level) states that exchange rates lead stock prices (Dornbusch and Fischer, 1980; Ajayi and Mongoue, 1996; Yau and Nieh, 2006), whereas portfolio approach (at the macroeconomic level) states that stock market mechanisms determine exchange rates. (Granger et al., 2000; Caporale et al. 2002; Pan et al. 2007).

Wang et al. (2010) use daily data to explore the impacts of fluctuations in crude oil price, gold price, and US dollar on the stock price indices of the United States, Germany, Japan, Taiwan, and China respectively. Their results show that there exist cointegration between fluctuations of oil price, gold price and the US dollar and the stock markets in Germany, Japan, Taiwan

and China. Sekmen (2011) explained the negative impact of the foreign exchange rate volatility on US stock prices by the rising costs associated with hedging foreign exchange rate risk. Olugbenga (2012) found significant influence of foreign exchange rates on the Nigerian stock market (as Nigeria is an oil exporting country). The author concluded that volatility of foreign exchange market could be used as predictor for stock market. Yoon and Kang (2012) examined price returns and volatility linkages between foreign exchange market and stock markets in South Korea from January 1990 to December 2009. They found strong causality from stock prices returns to foreign exchange rate returns. Their results suggest also that the Asian currency crisis from 1997 stimulated a bidirectional volatility spillover between the two markets. Chkili (2012), corroborates the significant mean transmissions and volatility spillovers from foreign exchange market to stock market in emerging countries and confirms that return shocks and volatility spillovers between the two markets are bidirectional in most cases and suggest that national investors in emerging countries should hold additional currency in order to reduce the risk of their portfolio investment.

3. Data and theoretical analysis

3.1. Presentation of the data and declaration of hypothesis

A special feature in the relationship among oil, gold, foreign exchanges and stock markets is that the magnitude of their interdependencies is illustrated in the informational contents of their respective prices. Generally, unusual events are summarized in stock markets dynamics and international oil price. We depict and discuss here theoretically bilateral relationships and then declare the hypothesis for each relation.

Oil price versus US dollar exchange rate

Focusing first on the link between oil price and the US dollar. At the start, we mention that oil as commodity is broadly invoiced in US dollar. It will be a relationship between a price and a good demanded by wide range of countries. Consequently, a negative correlation can arise

because changes in the US dollar exchange rate affect negatively oil price. More specifically, exchange rates can change oil price by way of an effect on oil supply and demand, and by financial markets. It's the *terms of trade*[1]. Backus and Crucini (2000), show that variation in oil price even determines most of the variation in the terms of trade. First, on the supply side of oil market, a depreciation of the USD may lead oil producers to limit oil supply and raise oil price to stabilize the purchasing power value of their exports in dollars. Yousefi and Wirjanto (2003, 2005) provide evidence on this channel. Second, a depreciation of the dollar value may also increase the global demand for oil, as oil imports become cheaper in local currency for countries besides the USA (De Schryder and Peersman 2013; Beckmann and Czudaj ; 2013). Moreover, several countries such as China peg their national money to the US dollar. Dependent on their oil consumption intensity, depreciation could lead to an increase in oil demand driven by higher exports (Bénassy-Quéré et al., 2007).

Exchange rates can also affect oil price directly through financial markets or indirectly through other financial assets, and particularly portfolio rebalancing and hedging practices. It's the *wealth effects*. As oil price is expressed in US dollar, oil futures may be good hedge against expected depreciations in the USD. Krugman (1983) and Golub (1983) document that higher oil price will transfer wealth from oil importers to oil exporters, which leads to a change in the exchange rate of the importing country through current account imbalances and portfolio reallocation. The last impact is associated with the dependence on oil and the share of exports to oil-exporting countries.

Other observers and academics argued that the negative correlation between exchange rates and oil price could be driven by monetary policy and interest rate changes in so far as a reduced interest rate in one country results in capital flights and then weakens purchased

[1] When the price of an import rises, in the presence of inelastic demand for that import (i.e. hardly demanded quantities fall at all when the price increase as is the case for oil), the trade balance get worse, which will decrease the value of the local currency.

power parity of the local currency in that country. Subsequently, national imports become expensive on international markets. At the same, a reduced interest rate by Federal Reserve (FED) weakens US dollar on international forex markets and then results in cheap imports of dollar-denominated commodities. In inflationary times, international investors may prefer to invest in real assets like oil, which drives oil price up of course when considering elasticity price. Akram (2009) finds that commodity prices increase in response to reductions in real interest rates.

From an historical illustrating perspective, after a stable oscillation of oil price between $10 and $36 a barrel, the intensity of the inverse relationship between Brent crude oil price and the US dollar has been left up since 2002. The year 2002 is therefore supposed to be the principal turning point in so far as, from the year of 2000 to 2002, oil price was clearly collapsed while the US dollar exchange rate incessantly appreciated. But since the year of 2002 the picture has wholly changed. Specifically, oil price has risen sharply while the USD has ever more depreciated. This trend peaked in 2008, when the effective dollar exchange rate weakened to a historical low in March and the average monthly price of Brent oil then reached an all-time high level of $134 a barrel in July.

Consequently, we expect to find a negative interaction and then declare the null hypothesis as follows:

***H_0*:** there is a negative relationship between oil price and US dollar exchange rate

Oil price versus stock market prices

For equity markets, there is evidence that higher oil price lower stock market prices, and that this effect mainly materializes through a demand channel associated with costs and profitability of listed firms (Kilian and Park, 2009; Masih et al., 2011). Oil price can affect stock prices directly by impacting future cash flows or indirectly through an impact on the discount factor (interest rate or wacc) of the future cash flows. In absence of complete

substitution effects between factors of production, rising oil price increase the cost of doing business and then reduce profits even for non-oil related companies. Profits and business information's of listed companies will be transmitted to stock markets. For the reverse effect, a positive stock market shock might results in higher expected earnings and growth of listed firms which involves additional economic activity and extra demand for oil. Demand shocks have been indeed widely held responsible for the evolution in oil price since 2003, as emerging economy commodity demand growth pushed oil price upwards (Kilian 2009, Lombardi and Van Robays 2011). Related to this fact, one enlightenment of the negative correlation between exchange rates and oil price could exactly be the great growth of demand in China, and other large BRICS economies, which lifted oil price upwards (from 2000 to 2008) and at the same time was associated with a weaker US dollar. The opposite evidence occurred with the slower growth in those countries since 2010 which helped bring oil price down in 2014 by demanding much less of it and appreciated the US dollar.

On the topic of uncertainty and risk aversion, there has been compelling evidence that a rise in financial market risk generally results in an appreciation of the USD (Bekaert et al., (2013) as US financial assets are perceived as safe and liquid, triggering what has been referred to as FTS (flight-to-safety) phenomenon (Fratzscher 2009). Oil price volatility has been also shown to increase in period of increased uncertainty (Van Robays 2016).

Accordingly, we expect to find a negative interaction and declare the null hypothesis as follows:

***H_1*:** there is a negative relationship between oil price and stock market prices

Oil price versus gold price

International oil and gold prices become sharing common features especially when talking about the financialization process of their trading. Zhang and Wei (2010) support the evidence that both commodity markets tend to be influenced by common factors, such as US dollar,

economic fundamentals and geopolitical events. Gold is often regarded as a substitute currency and a pretty safe haven for risk averter investors. Oil can also be used as an inflation hedge for asset portfolios because it is a significant driver of inflation, although developed economies have improved their energy efficiency and weakened inflation risk. Both oil and gold are likely to rise in response to a falling dollar, but their relationship is less straightforward than that as oil is perceived as risky asset and gold as the opposite. During periods of risk on trade, oil will be bought whereas gold is more likely to be sold, so there should be a negative correlation between them.

Moreover, an instantaneous thought suggests a direct causal relationship but a second argument supports an impact of oil on shares of gold listed companies and argues that the gold and oil prices are driven by a common factor through stock markets. In the main, oil-gold relationship obeys to three major theories:

First, oil influences gold.

One possible argument states that raising oil price is bad for the economy, dampening growth and dropping stock prices so investors look for alternative assets, such gold. Thus, oil price indirectly affects the price of gold.

Second, oil affects gold mines

Another line of thinking sees an inverse causation between oil price and stock prices of gold mining listed companies. Expensive oil makes gold extraction more expensive and therefore minimizes the profit margin of gold mines. This is because a big fraction of mine extraction consumes energy.

Third, inflation impact gold and oil

Both oil and gold trade are invoiced in the US dollar. Therefore, their pricing process depends on the strength of that currency, as driven by its inflation rate. It can be argued that sharing

similar trend is not because one influences the other, but because their prices are driven by a common factor: the US inflation rate.

The third theory is a reminder that correlation, meaning a similar pattern between two variables, does not necessarily imply causation. One explanation might be indeed causation: oil price influences directly gold price. As a result, we expect to find a close bidirectional relation while expressing some reservation about the sign of that relation. From where, we declare the null hypothesis as follows:

***H_2*:** there is a close relation between oil price and gold prices

Gold prices versus stock market prices

Gold is an accepted standard of value and is not subject to the same systematic risk that stock market is exposed to. So when business cycle collapses, stock exchanges and the dollar move downward and become less attractive. But gold becomes more pretty and its value increases as well. In fact, stock market expresses the soundness of national money to determine how nation's businesses get higher. However, this inverse relationship is frequently known as instable.

Therefore, we expect to observe a negative relation and then declare the null hypothesis as follows:

***H_3*:** there is a negative bidirectional relation between stock prices and gold prices

Gold prices versus US dollar

The correlation between gold and the US dollar seems to be awkward at the beginning, in so far as gold is priced in this currency. Would it not be impossible to settle on such relationship? Otherwise, the relationship between gold and a currency can be associated with the foreign exchange rate of that currency. As about the US dollar, the existing literature marks two facts:

Fact 1. Between 2004 and 2006, the correlation between gold and the US dollar Index was -0.44, between 1997 and 2006 it was -0.28, and between 1989 and 2006 the relationship was -0.28. It means an inverse correlation.

Fact 2. From 2001 until 2009 gold and the US dollar had a nearly perfect negative correlation. When gold price decreases, the dollar increases. However, since the end of 2009 this is no longer the case.

In fact, gold moved to floating exchange rates after 1971. This made its price exposed to the US dollar's external value. In 2008, the International Monetary Fund (or IMF) estimated that 40 – 50% of moves in gold prices since 2002 were dollar related. A 1% change in the effective external value of the US dollar lead to more than a 1% change in gold prices. First, a falling dollar increases the value of other countries' currencies which increases the demand for commodities including gold. Second, when the US dollar starts to losing its value – compared to its trading partners – investors look for alternative investment sources to store value. Gold is an alternative.

However, it's important to understand that it's possible for the USD and gold price to increase at the same time. This can occur in presence of a crisis in some other countries or regions. This would cause investors to flock to safer assets - the US dollar and gold. The US dollar is also driven by other factors - like monetary policy and inflation and economic prospects in the USA versus other countries. Investors and portfolio managers need to consider all of these factors as well as historical facts given that history may repeat itself.

Consequently, we expect to observe a negative relation and declare the null hypothesis as follows:

***H_4*:** There is a negative relation between US dollar and gold prices

US dollar versus Stock market prices

Generally, stock market can impact forex market in different ways. For instance, if the US stock market start getting higher registering impressive gains, we are likely to see a large influx of foreign investment into the USA, as international investors rush in to join the party. This influx of money would of course be very positive for the USD, because in order to participate in the equity market rising, foreign investors would have to convert their own domestic currency into US dollars. The opposite also holds true: if the stock market is bearing, foreign investors will most likely rush to sell their US equity holdings and convert USD's into their domestic currencies which would lead to substantially negative impacts on the dollar back. This fact can be applied to all other currencies and equity markets around the world. It is also the most basic usage of equity market flows to trade forex.

Results presented in previous studies are best mixed. Reasons behind the mixed results could be difference in specialization or in the trade volumes or there could be a difference in the degree of capital mobility. We go forward in the discussion of this relationship. The US dollar and stock market interactions have mostly one way: inverse relationship. The majority of impact flows from the dollar (cause) to the stock market (effect). The transmitted effects occur through three channels: (i) effects on exports, (ii) repatriated profits from abroad and (iii) foreign capital. (i) Stocks of US listed exporter companies, which rely on the competitiveness of their exports abroad, gain direct positive benefits from a weaker dollar. A weaker dollar increases. The companies benefit from increased foreign sales, and their equity prices rise when earnings are reported. (ii) According to the "National Center for Policy Analysis", the United States' share of world GDP is relatively constant at 26.7 percent in 2009, which means that there is more economic activity out of the country than there is inside the United States. For instance, Ford and McDonald's are getting more than 60 percent of their revenue from overseas. Companies doing that greatly business overseas will be strongly

affected by foreign exchange fluctuations against the dollar. If a company makes 1 million euros in profit, and the dollar falls in value, then those euros will translate to additional dollars. The market collapses when those extra unearned profits come in. It sounds ridiculous to look at companies for the strength of their business, but stock market involves a lot of perception, not just economic realities. (iii) The relative increase in foreign currencies from a depreciating dollar does not just benefit institutional investors but wealthy individuals overseas see that they can get more US dollars for their own currency and therefore buy more financial assets on the US stock market. As the institutional investors rise, and the dollar gets stronger, they can sell their now appreciated US dollars and convert them back into their domestic currency, thus getting a higher return than if they invested in their own currency.

We then expect to observe a negative relation and then declare the null hypothesis as follows:

***H_5*:** there is a negative bidirectional relation between stock market prices and US dollar

In figure 1, we summarize the all-party direct and indirect relationships, as detected in the literature and discussed theoretically before.

3.2. Statistical properties of variables

We use monthly data for the sampling period spanning from January 1995 to October 2015. The data are Brent crude oil price, gold price, broad trade weighted average of the foreign exchange values of the US dollar against the currencies of a broad group of major US trading partners, and the MSCI world stock market index. The data have been respectively sourced from the US Energy Information Administration, bank of England, Board of Governors of the Federal Reserve System and MSCI barra.

Other additional controls monthly data are: US interest rate (Effective Federal Funds Rate) used to control for monetary policy impacts, US CPI (Consumer Price Index) to control for socio-economic conditions, Chinese and US gross imports of crude oil as proxies for global economic outlooks, default premium as the differential between Baa and Aaa moody's rated

US corporate bonds to control for default risk effects as well as for financial and banking crises on international financial markets and finally, crude oil future contracts to control for investors' future expectations as well as the financialization process of oil markets. The all data have been obtained from Federal Reserve Economic Data and Energy Information Administration.

Table 1 reports descriptive statistics of monthly series. The series show common features as economic and financial data. First, they are evidence for a significant departure from the normality hypothesis according to the Jarque – Bera test. Then, the autocorrelation structure is examined using the Ljung – Box autocorrelation test of lags orders between 1 and 12. Results confirm significant serial auto-correlation and suggest that the information contained in past returns is relevant for forecasting purposes. Finally, their distributions are stationary at the 1% level, since the calculated ADF values are strictly below the critical threshold.

Bilateral unconditional correlations are also computed between the whole relevant variables (Table 2). The correlation coefficients between the all endogenous and exogenous variables present an average value equal to 15.25%. Correlation coefficients between the endogenous variables have an average value equal to 15.32%, while between the exogenous variables are 6.78%, which emphasizes the absence of redundant informations in the used additional regressors. It's worth noting that the unconditional correlations are informative only superficially.

4. Empirical methodology and econometric issues

The empirical methodology makes use of the simultaneous equation approach which allows to adequately investigating the multipart interactions among oil price, gold price, US dollar exchange rate and stock market prices. We then estimate the following system of equation simultaneously:

$$\mathrm{Stock}_t = \alpha_0 + \alpha_1 \mathrm{Oil}_t + \alpha_2 \mathrm{Gold}_t + \alpha_3 \mathrm{USD}_t + \alpha_4 X^s_{1t} \quad (1)$$

$$\mathrm{Oil}_t = \beta_0 + \beta_1 \mathrm{Gold}_t + \beta_2 \mathrm{USD}_t + \beta_3 \mathrm{Stock}_t + \beta_4 X^o_{2t} \quad (2)$$

$$Gold_t = \delta_0 + \delta_1 Oil_t + \delta_2 USD_t + \delta_3 Stock_t + \delta_4 X_{3t}^{g} \quad (3)$$

$$USD_t = \gamma_0 + \gamma_1 Oil_t + \gamma_2 Gold_t + \gamma_3 Stock_t + \gamma_4 X_{4t}^{d} \quad (4)$$

Oil price, gold price, US dollar exchange[2] rate and stock prices are all endogenous variables and X_i (i = 1 , …, 4) contains vectors of their exogenous determinants as additional controls needed to achieve identification. A fine identification of the system requires differences between X_i. Accordingly, the vector of exogenous variables X_i (i = 1 , …, 4) consists in monetary policy and default premium for X_1^s, oil gross imports and oil future contracts, as representation of oil market financialization process, for X_2^o, and monetary policy and consumer confidence index for X_4^d.

All variables have been introduced in the estimated system at time "t", except for oil future price which has been introduced at time "t+1", in order to capture investors and markets expectations on oil price and their implications on economic outlooks as well as on stock markets dynamics.

Masih et al. (2011), and Haug and Sadorsky (2012) interested in α_1 arguing that higher oil price lower stock markets. Yousefi and Wirjanto (2005) focus on β_2 while Zhang and Wei (2010) and Fratzscher(2014) focuse on both β_2 and γ_1 and observed bilateral causality. Sekmen (2011) studied α_3 in USA, Olugbenga (2012) focuses on α_3 on Nigerian stock market, while Yoo and Kang (2012) studied α_3 on South Korean context and finds strong causality between foreign exchange and stock market. Narayan et al. (2010) finding bidirectional causality between oil price and gold price (β_1 and δ_1) and later Le and Chang (2012) confirmed the close link between them. More recently, Wang and Chueh (2013) interested in δ_1 and find positive interaction between oil and gold. Sumner et al.(2010) and Gaur and Bansal (2010) focus on δ_3 arguing that falling stock market results in rising gold prices.

[2] The broad index is a weighted average of the foreign exchange values of the US dollar against the currencies of a large group of major US trading partners. The index weights, which change over time, are derived from US export shares and from US and foreign import shares. For details on the construction of the weights, see the article in the Winter 2005 Federal Reserve Bulletin.

Bekaert et al. (2013) paid attention to γ_3 arguing that raises in financial market risk generally results in an appreciation of the USD. Finaly, Wang et al.(2010) interested in α_1, α_2 and α_3 and find cointegration between fluctuations of oil price, gold price and the USD in one side and stock market in the other side in Germany, Japan, Taiwan and China.

It's worth noting here that although previous studies interested in direct relationships we do not observe consistent investigation on indirect relationships as well as an exploration of possible simultaneous multipart interactions. The simultaneous equations estimation allows to concluding about both direct and indirect relationships. Direct effects of each variable can be observed through its associated coefficient while indirect effects can be decomposed into more than one component. Theoretical interpretation of the model allows providing plausible insights since we aim at exploring the direct and indirect effects. For instance, the direct effect of gold on stock show that a change in gold price by one unit can also induce a change in stock prices by α_2 and the direct effect of US dollar can be represented by α_3. The indirect effect of US dollar on stock, taking into account the role of crude oil price can be determined by the derivative of stock prices with respect to US dollar which is equal to:

$$\frac{\partial \,\text{stock market}}{\partial \,\text{US dollar}} = \alpha_1 \frac{\partial \,\text{oil}}{\partial \,\text{US dollar}} = \alpha_1 \beta_2 \tag{5}$$

The total effect of the US dollar on stock, taking into account the role that may play oil price as transmission channel, in the simultaneous equations estimation is represented by the derivatives of stock with respect to US dollar:

$$\frac{\partial \,\text{stock market}}{\partial \,\text{US dollar}} = \alpha_3 + \alpha_1 \frac{\partial \,\text{oil}}{\partial \,\text{US dollar}} + \alpha_1 \frac{\partial \,\text{X}_2^{\text{oil}}}{\partial \,\text{US dollar}} \tag{6}$$

Which is equal to $\alpha_3 + \alpha_1\beta_2 + \alpha_1\beta_4 = \alpha_3 + \alpha_1(\beta_2 + \beta_4)$. The third term captures the magnitude of the financialization degree of the dollar or the financialization of international oil markets.

5. Empirical results and discussion

Table 3 reports estimation results of the simultaneous equation system. We rely here on the relative contribution of direct and indirect effects and then put emphasize on the total effect.

Equation (1), shows that stock market is positively and significantly affected by oil price, gold price and USD exchange rate and US interest rate. Changes in default premium have as well a positive effect on stock market prices. The direct effects support the traditional approach and recent findings of Wang et al (2010) and Sekmen (2011). Regarding their indirect effects, changes in those variables result in significant negative influence on stock prices. The switch from positive direct effect to negative indirect effect may be explained by the nature of the relationship between stock market prices and the channels through which the indirect effect has been produced. As about the total effects, the negative relationship between oil price and stock markets corroborate results of Malik and Hamoudeh (2007) on Gulf stock markets, Oberndorfer (2009) on European stock markets and afterward Masih et al. (2011), and Haug and Sadorsky (2012) on emerging markets. The US economic and monetary policy (as represented by broad trade weighted US dollar exchange rate, US interest rate and US CPI) result in significant unrest on international stock markets. Indeed, expectations on economic conditions will be behaviorally transmitted to stock market such as speculative, herding or hedging reactions.

Equation (2), points out that oil price is positively affected by stock markets and significantly by gold prices and USD exchange rate and support findings of Wang and Chueh (2013) and Reboredo (2013) for positive interaction between oil and gold. Crude oil price is also significantly affected by oil futures price as well as by Chinese oil gross imports. In the framework of indirect effects, oil price is affected significantly by gold price, stock market behaviors, and US socio-economic conditions as represented in consumption price index and interest rate. The corporate default premium has an indirect negative effect on international oil

price. Chinese oil gross imports have as well a negative influence on international oil price. We explain this evidence by the fact that worldwide demand on oil commodity is associated with corporate risk rating. Tang and Xiong (2012) state that as a result of the financialization process, oil price become increasingly correlated with futures prices of non energy commodities after 2004. The total effects confirm the existing direct and indirect influences on oil price and corroborate findings of Yousefi and Wirjanto (2005), that USD exchange rate affect oil price via demand and supply on international markets and support recent results of Zhang and Wei (2010) and Fratzscher et al. (2014) for bidirectional causality between oil and USD and results of Le and Chang (2012) about the close link between prices of oil and gold.

Equation (3), shows that gold prices on international markets are positively and significantly affected by oil price and USD broad exchange rates. Changes in stock market prices have a negative effect on gold prices. This evidence is very plausible and support findings of Saumner et al. (2010) and Gaur Bansal (2010) that falling stock markets results in rising gold prices. The current results confirm our theoretical analysis as well as the previous literature. We cite inter alia, Zhang and Wei (2010), Le and Chang (2012). The indirect effects confirm the close tie between gold and oil and USD. International Gold prices are also indirectly and significantly affected by US consumer price index, US interest rates, oil futures prices and Chinese oil gross imports. Regarding the total effects, gold prices are concerned by changes in oil price, stock markets, USD broad exchange rate, US inflation and US interest rate, oil futures prices and Chinese oil gross imports. It deserves to note here that US oil gross imports and default premium have slight effects on gold prices but the informational content of international gold prices are best representing of global economic and financial outlooks.

Equation (4), points out that broad US dollar exchange rate is negatively and significantly affected by oil, gold and stock prices but positively affected by US consumer price index. The present findings confirm the theoretical analysis and the existing empirical literature

especially the portfolio approach which argue that stock market mechanisms determines exchange rates (Granger et al. (2000), Caporale et al. (2002), Pan et al. (2007) and recently Bekaert et al. (2013). The USD is also indirectly ans significantly affected by US CPI, oil futures prices and Chinese oil gross imports. The total effects confirm the negative and significant effects of crude oil price, gold price and stock market prices (bodenstein et al. 2011, and Jean-Pierre Allerget, 2014), and effects of the other additional controls.

Figures 2, provide some intuition about the issue under scrutiny by plotting bilateral interactions between endogenous variables. All illustrations present bilateral relationships and confirm the stated hypothesis and obtained results while the last one reports the multipart interactions. It confirms the close link between oil and US dollar and between gold and stock markets. A falling stock market results in strong worldwide demand for gold as safe haven. The bilateral direct interaction is then negative in the short run but positive or cointegrated in the long run.

The figure 3, summarizes estimation results on the multi-part relations among oil, gold, US dollar and stock market. Asterisk translates significance of the estimated coefficients.

6. Conclusion

The interdependencies among oil price, gold price, US dollar and stock markets put forward fundamental importance for either investment or managerial decisions.

The aim of this article is to highlight the interdependencies between the all-parties using the simultaneous equation approach for the period 1995 – 2015. Our findings show the evidence of factual effect as well as significant interactions among oil price, gold price, US dollar and stock prices. Indeed, we found negative relations between oil price and stock market prices but oil price is significantly affected by stock markets, gold and trade weighted USD exchange rate. Oil price is also affected by oil future prices as well as by Chinese oil gross imports. Gold prices are concerned by changes in oil, USD and stock markets but slightly

depend on US oil gross imports and default premium. The trade weighted USD exchange rate is significantly affected by oil price, gold price and stock market prices. The USD broad exchange rate is also negatively affected by the US consumer price index. Indirect effects always exist which confirm the presence of global interdependencies and highlights the financialization process of commodity markets. We explain the obtained results by the increased use of oil and gold as financial assets either for speculation or for hedging, which intensified direct and indirect ties between the all markets and thus confirm that the performance of these markets become dependent between each other. Moreover, we note many variables to consider over such interdependencies. Undeniably, new oil suppliers, the less US dependency on foreign oil, the current Chine's slowed economy and the continued struggles of emerging markets and the trend to softer world economy in addition to the present strategic and geopolitical events move all forward these challenges to be drivers over crude oil, gold and US dollar beyond this decade.

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Table 1. Basic statistics of all used variables

Variables	Mean	Std. Dev.	Skewness	Kurtosis	Jarque-Bera	Q(1)	Q(12)	ADF statistics
US Dollar	108.5568	9.8636	0.2953	2.0792	12.465^{+++}	245.11^{+++}	2967.1^{+++}	-1.865
Gold	720.8594	471.4113	0.7653	2.1506	31.916^{+++}	250.31^{+++}	4268.7^{+++}	-0.529
Stocks	1180.795	292.0291	0.1796	2.2531	7.155^{+++}	238.35^{+++}	1930^{+++}	-1.493
Oil	54.6411	35.5244	0.5285	1.8839	24.613^{+++}	246.55^{+++}	2387.8^{+++}	-1.858
US. CPI	195.5986	27.6063	0.0157	1.6316	19.514^{+++}	247.77^{+++}	2693^{+++}	-0.544
US. IR	2.7448	2.3644	0.1374	1.3070	30.642^{+++}	249.08^{+++}	2474.6^{+++}	-1.493
OFP	53.0568	31.6216	0.4502	1.8972	21.114^{+++}	245.42^{+++}	2257.4^{+++}	-2.059
DP	7.3197	101.5463	15.7139	247.9525	635306.7^{+++}	0.0047^{+++}	0.0564^{+++}	-11.949^{+++}
US OIL Imp.	11356.52	1554.577	0.0708	2.0612	9.391^{+++}	220.16^{+++}	2098.9^{+++}	-23.048^{+++}
CN OIL Imp.	280.3288	59.7369	0.6453	2.9955	17.354^{+++}	149.38^{+++}	1544.8^{+++}	-15.495^{+++}

Notes: Columns 1 – 5 are reserved to the mean (%), the standard deviation (%), the skewness, the kurtosis and the Jarque and Bera normality test statistics. Q(1) and Q(12) are statistics of the Ljung-Box autocorrelation test applied to returns with lags between 1 and 12. ADF is the statistics of the Augmented Dickey and Fuller (1981) test conducted without constant and time trend. Significant results at 1% levels are indicated by ($^{+++}$).

Table 2. Pairwise unconditional Correlations

	Dollar	Gold	Stocks	Oil	US. CPI.	US. IR.	OFP	DP	US. OIL. Import.	CN. OIL. Import.
US Dollar	1,000									
Gold	-0,532	1,000								
Stocks	-0,074	0,532	1,000							
Oil	-0,530	0,893	0,630	1,000						
US. CPI.	-0,266	0,885	0,718	0,886	1,000					
US. IR.	0,098	-0,739	-0,282	-0,636	-0,798	1,000				
OFP.	-0,512	0,845	0,631	0,978	0,885	-0,623	1,000			
DP.	0,052	-0,057	0,054	-0,047	-0,055	0,081	-0,046	1,000		
US. OIL. I.	0,251	-0,165	0,081	0,106	0,107	0,013	0,160	-0,014	1,000	
CN. OIL. I.	-0,258	0,612	0,590	0,725	0,778	-0,532	0,753	-0,042	0,351	1,000

Table 3. Estimation results

Variables	Direct Effects	Indirect effects	Total effects
	Coef. [std. dev.]	Coef. [std. dev.]	Coef. [std. dev.]
Crude Oil price			
Oil	—	0.0332*** [0.0125]	0.0332*** [0.0125]
Gold	0.0153*** [0.0021]	-0.0114*** [0.0011]	0.0038* [0.0023]
USD	0.1415**[0.0641]	0.0063 [0.0305]	0.1478** [0.0674]
Stock	0.0020[0.0021]	-0.0069*** [0.0010]	-0.0049** [0.0023]
US CPI	—	0.01648*** [0.0337]	0.1648*** [0.0337]
US IR	—	-0.6022*** [0.1921]	-0.6022*** [0.1922]
DP	—	-0.0004 [0.0006]	-0.0004 [0.0006]
OFP	0.9432***[0.0391]	0.0313 [0.0252]	0.9745*** [0.0292]
US Oil import	0.0001 [0.0004]	4.28e-06 [0.00001]	0.0001 [0.0004]
CN Oil import	-0.0193* [0.0111]	-0.0006 [0.0007]	-0.0199* [0.0116]
Const.	-20.2239*** [6.1672]	—	—
Gold price			
Gold	—	-0.5586*** [0.0567]	-0.5586*** [0.0567]
Oil	17.8585*** [1.6889]	-12.1336*** [0.9018]	5.7249*** [1.0333]
USD	34.4538*** [6.6154]	-28.0662*** [3.7046]	6.3876** [3.1927]
Stock	-0.2607 [0.1803]	-0.1033 [0.1200]	-0.3639*** [0.0804]
US CPI	—	7.1211*** [1.1059]	7.1211*** [1.1059]
US IR	—	-44.1064*** [7.6078]	-44.1064*** [7.6078]
DP	—	-0.0327 [0.0475]	-0.0327 [0.0475]
OFP	—	5.3998*** [0.8521]	5.3998*** [0.8521]
US Oil import	—	0.0007 [0.0022]	0.0007 [0.0022]
CN Oil import	—	0.1104* [0.0648]	-0.1104* [0.0648]
Const.	-3687.348***[721.1831]	—	—
US dollar			
USD	—	-0.8058*** [0.1190]	-0.8058*** [0.1190]
Oil	-0.1039* [0.0562]	-0.2708*** [0.0526]	-0.3747*** [0.0328]
Gold	-0.0517*** [0.0068]	0.0327*** [0.0054]	-0.0190*** [0.0016]
Stock	-0.0407*** [0.0068]	0.0370*** [0.0056]	-0.0037 [0.0041]
US CPI	1.1148*** [0.1202]	-0.8984*** [0.1459]	0.2164*** [0.0431]
US IR	—	-0.4494 [0.2968]	-0.4494 [0.2967]
DP	—	-0.0003 [0.0005]	-0.0003 [0.0005]
OFP	—	-0.3535*** [0.0335]	-0.3535*** [0.0335]
US Oil import	—	-0.00005 [0.0001]	-0.00005 [0.0001]
CN Oil import	—	0.0072* [0.0042]	0.0072* [0.0042]
Const.	-18.4043 [13.8534]	—	—
Stock market			
Stock	—	-0.4343*** [0.0846]	-0.4343*** [0.0845]
Oil	4.1045*** [1.0856]	-4.8112*** [0.7209]	-0.7067 [1.0167]
Gold	0.8677*** [0.1070]	-0.9716*** [0.0871]	-0.1039 [0.1022]
USD	26.4588*** [2.4047]	-15.1723*** [1.0831]	11.2865*** [1.6721]
US CPI	—	12.5826*** [0.7475]	12.5826*** [0.7475]
US IR	121.185*** [11.0378]	-52.6349*** [9.1257]	68.5474*** [5.3205]
DP	0.0898 [0.1293]	-0.0390 [0.0561]	0.0508 [0.0734]
OFP	—	0.6665 [0.6495]	-0.6665 [0.6495]
US Oil import	—	-0.0001 [0.0003]	-0.0001 [0.0003]
CN Oil import	—	0.0136 [0.0158]	0.0136 [0.0158]
Const.	-2874.573***[316.657]	—	—
Log-likelihood	-12441.742		
Chi2	325.01 (0.0000)		
#Obs.	250	250	250

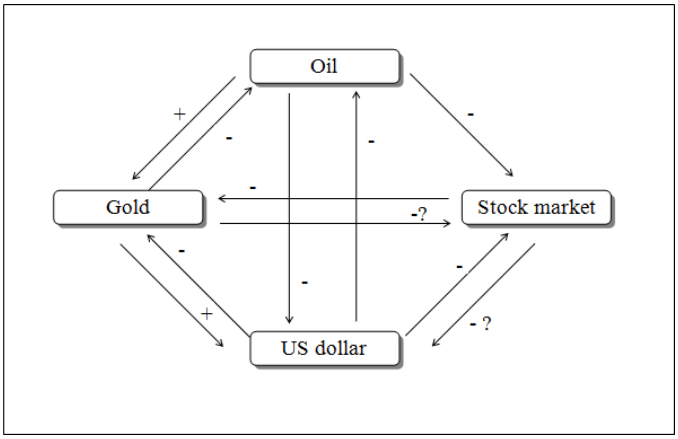
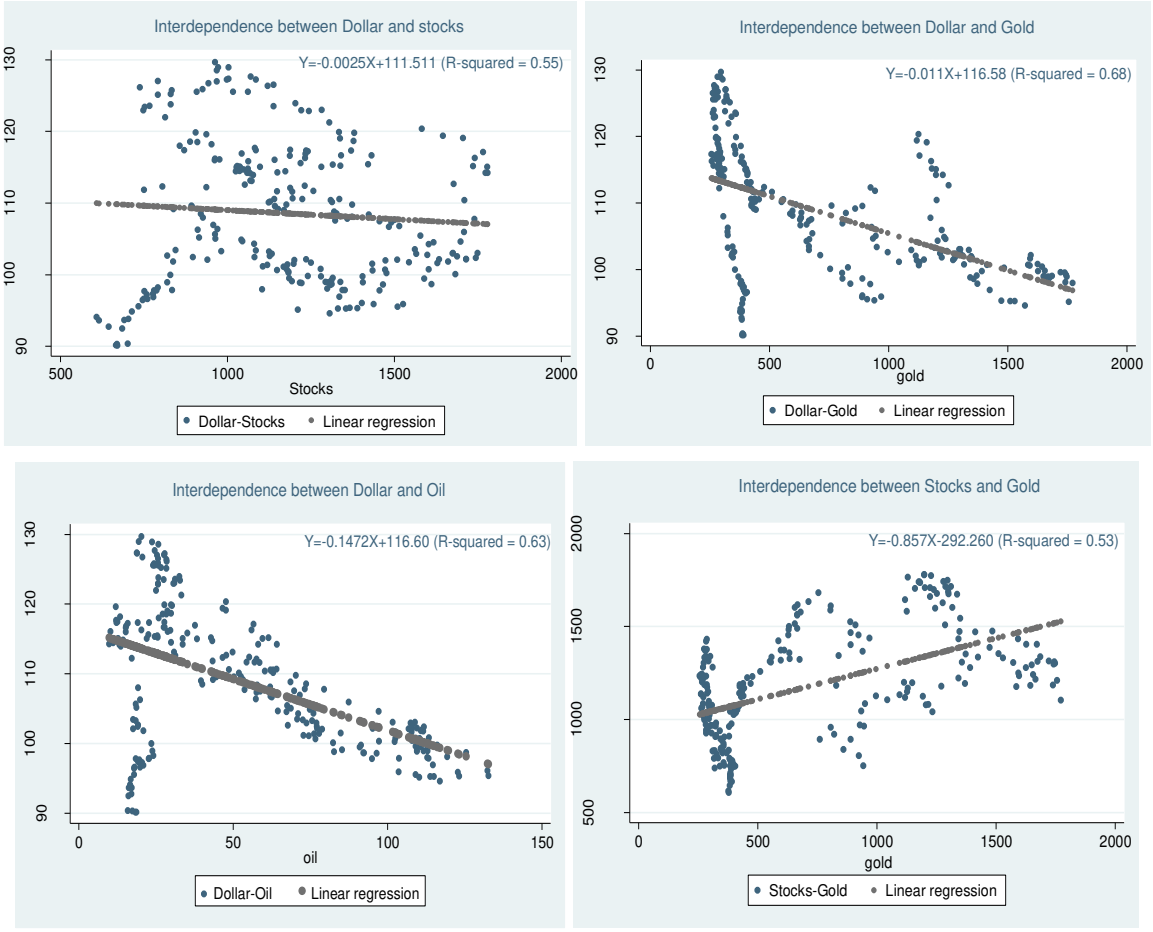


Figure 1. Direct and indirect relationships: evidence from the literature



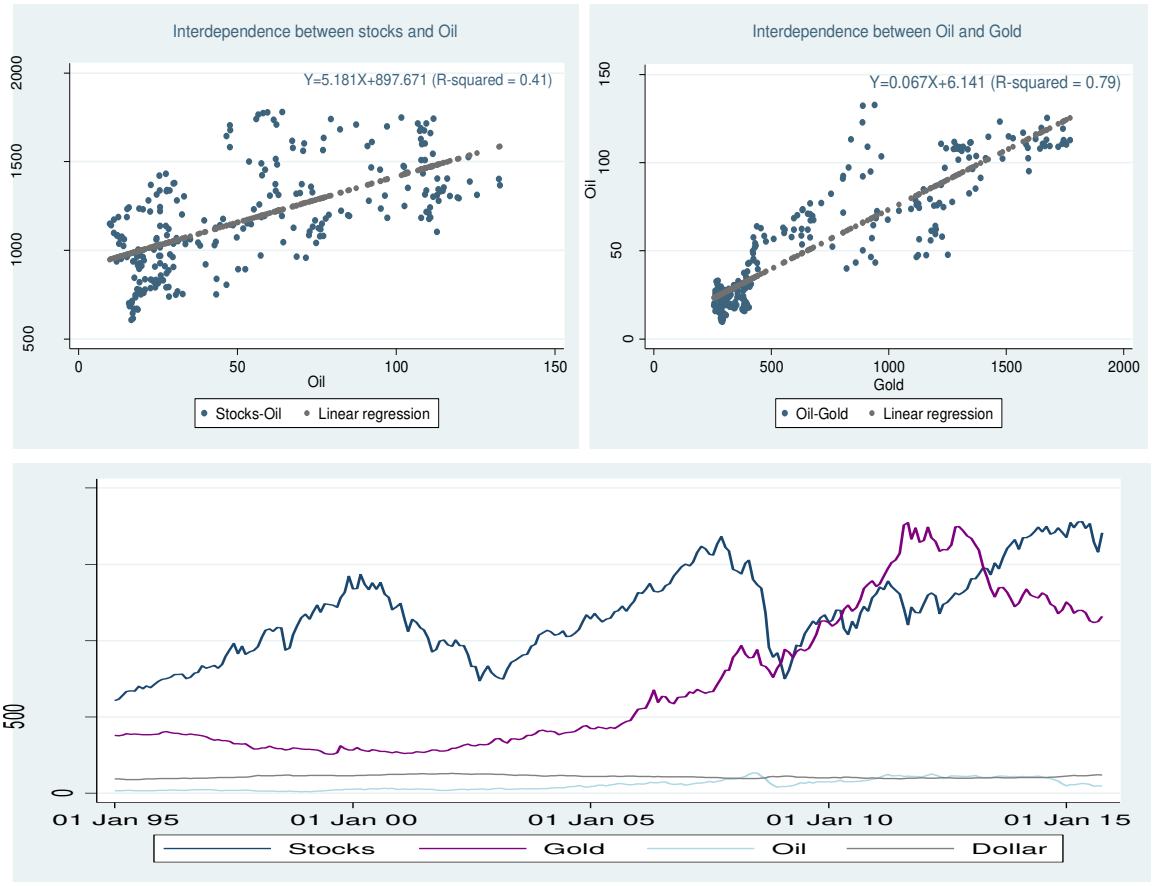


Figure 2. Bilateral interdependencies between the relevant endogenous variables

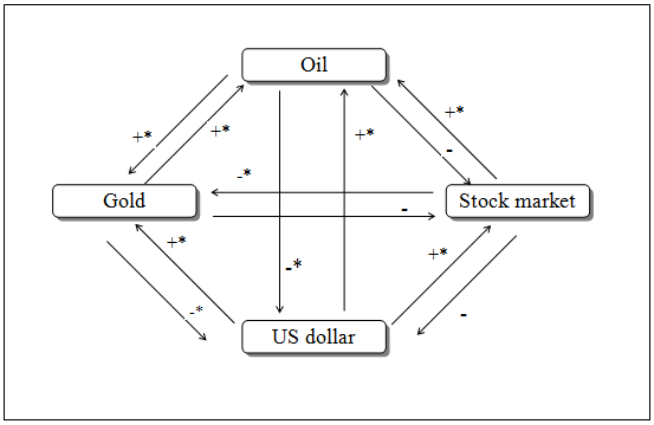


Fig. 3. Direct and indirect relationships: evidence from estimation results