Received 27 December 2016
Revised 10 June 2017
Accepted 15 August 2017

Oil, gold, US dollar and stock market interdependencies: a global analytical insight

Mongi Arfaoui
Faculty of Economics and Management of Mahdia, University of Monastir, Mahdia, Tunisia, and
Aymen Ben Rejeb
High Institute of Management of Sousse, University of Sousse, Sousse, Tunisia

Abstract

Purpose – The purpose of this paper is to examine, in a global perspective, the oil, gold, US dollar and stock prices interdependencies and to identify instantaneously direct and indirect linkages among them.
Design/methodology/approach – A methodology based on simultaneous equations system was used to identify direct and indirect linkages for the period 1995-2015. The authors try initially to find theoretical answers to main question of the study by discussing causal bilateral relationships while focusing on multilateral interactions.
Findings – The results show significant interactions between all markets. The authors found a negative relation between oil and stock prices but oil price is significantly and positively affected by gold and USD. Oil price is also affected by oil futures prices and by Chinese oil gross imports. Gold rate is concerned by changes in oil, USD and stock markets. The US dollar is negatively affected by stock market and significantly by oil and gold price. Indirect effects always exist which confirm the presence of global interdependencies and involve the financialization process of commodity markets.
Originality/value – Motivation of this research paper is the substantial implications of price movements on real economy and financial markets. Understanding that co-movement has great value for investors, policy makers and portfolio managers. This paper differs from previous studies in several aspects. First, most of the research papers focus on bilateral linkages solely, while the authors' investigation was implemented on all the four markets simultaneously. Second, the study was developed in a global framework using international data. The global analysis allows avoiding country specific effects.

Keywords Stock market, Oil price, Gold price, Trade-weighted exchange rate, Simultaneous equations
Paper type Research paper

1. Introduction

The sustained rise in interdependence of global markets along with the international financial integration have accelerated the financialization process of commodity markets (Tang and Xiong, 2012) and led stock and foreign exchange (hereafter forex) 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 market risk 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" but also as a alternative investment with greater sense of certainty during turmoil periods (Baur and McDermott, 2010).

JEL Classification — F31, G15, Q02

European Journal of Management and Business Economics
Vol. 26 No. 3, 2017
pp. 278-293
Emerald Publishing Limited
2444-8451
DOI 10.1108/EJMBE-10-2017-016

Oil and gold are the most widely traded commodities that have become among the most popular economic indicators.

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

We motivate this research paper by the substantial implications of price movements of the present assets and commodities on real economy and financial markets. Therefore, understanding their co-movement prices has great meaning for portfolio managers and policy makers.

The aim of this study is to highlight the interdependent relationships between all the markets. We try to perform 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 using international data. Indeed, we employ Brent crude oil price, international gold price, 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, and corporate default risk were 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 equation system which allows studying all these linkages and grants on the possibility of more adequately investigating the complex system of interactions among oil, gold, forex and stock prices. This approach allows relying on potential links via other indirect effects. We then specify an equation to each endogenous variable, which includes the other endogenous variables as exogenous, and other exogenous variables to capture indirect effects. Fundamentally, we attempt to answer the following questions: to what extent oil, gold, forex and stock market are interdependent? And what nature and direction of effects portray their interdependencies?

The main results founded show significant interactions between oil price, gold rate, USD and stock prices. Indeed, we found that oil price is significantly affected by stock markets, gold and trade-weighted USD exchange rate. Oil price is also affected by oil futures price as well as by Chinese oil gross imports. Gold price is concerned by changes in oil, USD and stock markets but slightly depends on US oil imports and default premium. The USD exchange rate is significantly affected by oil, gold and stock market prices. The USD is also negatively affected by US consumer price index (CPI). We note that indirect effects exist which confirm the presence of global interdependencies and the 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 intensifies such interdependencies.

This paper differs from similar previous studies in several aspects. First, most of research papers focus on bilateral linkages such as oil vs stock markets (Jones and Kaul, 1996; Arouri *et al.*, 2012; Mollick and Assefa, 2013), oil price vs gold price (Ewing and Malik, 2013), gold prices vs stock markets (Gaur and Bansal, 2010; and Le and Chang, 2012), oil price vs exchange rates (Basher *et al.*, 2012) and other on trilateral linkages such as oil price, exchange rates and stock prices (Olugbenga, 2012; Fratzscher *et al.*, 2014).

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. The global analysis allows 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 equation approach makes it possible to answer to many questions associated with bilateral interactions and 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. 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 and a theoretical analysis and then 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

The relationships between financial and commodity markets are documented in a sizeable literature. We present and discuss here bilateral relationships with an interest in multilateral interactions.

2.1 Oil price vs US dollar exchange rate

The relation between oil price and exchange rates was initially documented by Golub (1983) and Krugman (1983) who put forth compelling arguments as to why the 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 (1983) analysis is based on the relationship among portfolio investment preferences of oil exporters and exchange rates movements. Indeed, rising oil price will increase portfolio investment possibilities of oil exporters. In Krugman's (1983) analysis, exchange rate movements are determined primarily by current account movements. If rising oil price lead to deterioration of country's current account, then exchange rates will fall. More recent evidence on this effect can be found in the study of Bodenstein *et al.* (2011), Jean-Pierre Allegret *et al.* (2014), etc.

Sadorsky (2000) found that exchange rates impact oil prices. 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.

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 on oil price, but a sizeable and significant effect via shocks on interest rates and risk. Similarly, the effects of shocks on both oil price and the US dollar are 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.

2.2 Oil price vs stock prices

The literature includes various studies that confirm the interdependency between oil price and stock prices. For instance, Basher and Sadorsky (2006) reported strong evidence that oil price risk impacts stock returns on emerging markets. Miller and Ratti (2009) used a VECM

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) was interested in the period 2002-2007, using both ARCH and GARCH models and found that rises in oil prices affect the European stock returns negatively. Basher *et al.* (2012) used an SVAR 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.

On balance, these studies confirm the evidence that changes in oil price have an effect on stock prices.

2.3 Oil price vs gold price

Melvin and Sultan (1990) contended that both changes in oil price and political unrests are significant determinants of gold rate. Narayan *et al.* (2010) was 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 the presence of common factors effect, Tang and Xiong (2012) stated that as a result of the financialization process, futures prices of non-energy commodities became increasingly correlated with oil after 2004. This trend has been triggered by the sub-prime crisis. Zhang and Wei (2010) analyzed cointegration and causality between gold and oil prices and found that there are consistent trends between oil price and gold price with a significant positive correlation during the sampling period 2000-2008. They observed in advance that oil price dynamics linearly Granger cause volatility of gold price.

Reboredo (2013) analyzed the oil-gold dependence structure using copula approach for the period 2000-2011, and found a positive and significant relationship between them suggesting that gold cannot hedge against oil price volatility. Wang and Chueh (2013) found positive interaction between gold and oil prices for the period 1989-2007.

2.4 Gold price vs stock market prices

Gaur and Bansal (2010) confirmed that, in periods of crisis, falling stock market always results in rising gold rates. Le and Chang (2012) found a significant relationship between stock market prices and gold prices and stated 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.

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.

2.5 US dollar vs Stock market prices

As far as the relationship between stock market and forex is concerned, the existing literature endows with paradoxical reasoning. Traditional approach (at microeconomic level) states that exchange rates lead stock prices (Dornbusch and Fischer, 1980; 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).

Wang *et al.* (2010) used daily data to explore the impacts of fluctuations in crude oil price, gold price, and US dollar on stock price indices of the US, Germany, Japan, Taiwan and China. The results show that there exist cointegration between fluctuations in 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 exchange rate volatility on US stock prices by the rising costs associated with hedging foreign exchange rate risk. Olugbenga (2012) found a significant influence of foreign exchange rates on the Nigerian stock market (as Nigeria is an

oil-exporting country). The author concluded that volatility of forex market could be used as predictor for stock market. Kang and Yoon (2013) examined price returns and volatility linkages between forex market and stock markets in South Korea from January 1990 to December 2009. They found strong causality from stock prices returns to forex returns.

3. Data and theoretical analysis

3.1 Presentation of the data and declaration of hypothesis

A special feature in the relationship among oil, gold, forex 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 market dynamics and international oil price. We depict and discuss here theoretically bilateral relationships and then declare the hypothesis for each relation.

Oil price vs US dollar exchange rate. The focus is first on the link between oil price and the US dollar. In the beginning, we mentioned that oil as commodity is broadly invoiced in USD. It will be a close relationship between a price and a good demanded by wide range of countries. Consequently, a negative correlation can arise because changes in the USD exchange rate affect oil price negatively. 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 Mario (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 to raise oil price and stabilize their positions 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, 2015; 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 is the wealth effects. As oil price is expressed in USD, oil futures may be a good hedge against expected depreciations in the USD. Krugman (1983) and Golub (1983) documented 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 PPP of the local currency in that country. Subsequently, national imports become expensive on international markets. At the same time, 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 the elasticity price. 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 vs stock market prices. For equity markets, there is evidence that higher oil price lowers 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). Demand shocks are 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 Robays, 2011). Accordingly, one enlightenment of the negative correlation between exchange rates and oil price could exactly be the great growth of demand in China, and BRICS's 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 USD.

On the topic of uncertainty and risk aversion, there exists 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 is referred to as FTS (flight-to-safety) phenomenon (Fratzscher, 2009). Oil price volatility increases in period of improved uncertainty (Robays, 2016). Accordingly, we expect to find a negative interaction and declare the null hypothesis as follows:

H1. There is a negative relationship between oil price and stock market prices.

Oil price vs gold price. International oil and gold prices share common features, especially when they are traded either for hedging or speculation purposes. 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 aversion. 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 bilateral 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:

(1) 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 as gold. Thus, oil price indirectly affects the price of gold.

(2) Second, oil affects gold mines: another view 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.

(3) Third, inflation impacts gold and oil: both oil and gold trade are invoiced in the USD. 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 directly influences gold price. As a result, we expect to find a close bidirectional relation while expressing a reservation about the sign of that relation. From where, we declare the null hypothesis as follows:

H2. There is a close relation between oil price and gold price.

Gold prices vs 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 unstable. Therefore, we expect to observe a negative relation and then declare the null hypothesis as follows:

H3. There is a negative bidirectional relation between stock prices and gold rate.

Gold prices vs 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 USD 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 USD's external value. In 2008, the IMF estimated that 40-50 percent of moves in gold price since 2002 were dollar related. A 1 percent change in the effective external value of the US dollar leads to more than a 1 percent change in gold price. First, a falling dollar increases the value of other local currencies which increases the demand for commodities including gold. Second, when the USD starts losing its value – compared to its trading partners – investors look for alternative investment sources to store value, which is gold.

However, it's important to realize 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 – USD and gold. The USD is also driven by other factors – like monetary policy and inflation and economic prospects in the USA vs 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:

H4. There is a negative relation between US dollar and gold price.

US dollar vs stock market prices. Generally, stock market can impact forex 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. 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.

The results presented in previous studies are best mixed. The 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: effects on exports, repatriated profits from abroad and foreign capital. Effects on exports: stocks of US-listed exporter companies, which rely on the competitiveness of their exports abroad, gain direct positive benefits from a weaker dollar. As weaker dollar increases. The companies benefit from increased foreign sales, and their equity prices rise when earnings are reported. Repatriated profits from abroad: According to the "National Center for Policy Analysis", the US' share of world GDP is relatively constant at 26.7 percent since 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 business overseas that greatly 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. Foreign capital: the relative increase in foreign currencies from a depreciating dollar does not just benefit institutional investors but also 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 USDs 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:

H5. 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 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

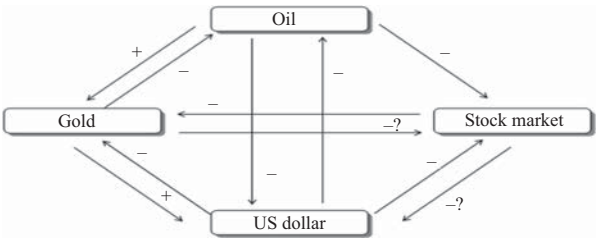

Figure 1.
Direct and indirect relationships: evidence from the literature

corporate bonds to control for default risk effects as well as for financial and banking crises on international financial markets and, finally, crude oil futures contracts to control for investors' expectations as well as the financialization process of oil markets. All the data have been obtained from Federal Reserve Economic Data and Energy Information Administration[2].

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 rate, US dollar exchange rate and stock market prices. We then estimate the following system of equation simultaneously:

$$Stock_t = \alpha_0 + \alpha_1 Oil_t + \alpha_2 Gold_t + \alpha_3 USD_t + \alpha_4 X^s_{1t} \quad (1)$$

$$Oil_t = \beta_0 + \beta_1 Gold_t + \beta_2 USD_t + \beta_3 Stock_t + \beta_4 X^o_{2t} \quad (2)$$

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

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

Oil price, gold price, US dollar exchange[3] rate and stock prices are all endogenous variables and X_i ($i = 1, \ldots, 4$) 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 ($i = 1, \ldots, 4$) consists in monetary policy and default premium for X^s_1, oil gross imports and oil futures contracts, as representation of oil market financialization process, for X^o_2, and monetary policy and consumer confidence index for X^d_4.

All variables were introduced in the system at time "*t*," except for oil futures price which is introduced at time "$t+1$," in order to capture markets expectations on oil price and their implications on economic outlooks and stock markets dynamics.

Masih *et al.* (2011) and Basher *et al.* (2012) were interested in α_1 arguing that higher oil price lowers stock markets. Yousefi and Wirjanto (2005) focused on β_2 while Zhang and Wei (2010) and Fratzscher *et al.* (2014) focused on both β_2 and γ_1 and observed bilateral causality. Sekmen (2011) studied α_3 in the USA, Olugbenga (2012) focused on α_3 on Nigerian stock market, while Kang and Yoon (2013) studied α_3 on South Korean context and finds strong causality between foreign exchange and stock market. Narayan *et al.* (2010) found 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) were interested in δ_1 and found positive interaction between oil and gold. Gaur and Bansal (2010) focused on δ_3 arguing that falling stock market results in rising gold price. Bekaert *et al.* (2013) paid attention to γ_3 arguing that rise in financial market risk generally results in an appreciation of the USD. Finally, Wang *et al.* (2010) were interested in α_1, α_2 and α_3 and found cointegration between fluctuations of oil price, gold price and the USD on one side and stock market on the other side in Germany, Japan, Taiwan and China.

It's worth noting here that although previous studies were 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 equation 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 shows 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:

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

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 the US dollar:

$$\frac{\partial\ stock\ market}{\partial\ US\ dollar} = \alpha_3 + \alpha_1 \frac{\partial\ oil}{\partial\ US\ dollar} + \alpha_1 \frac{\partial\ X_2^{oil}}{\partial\ US\ dollar} \tag{6}$$

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 I 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, USD and the US interest rate. Also, changes in default premium have 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 a 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 was produced. As for the total effects, the negative relationship between oil price and stock markets corroborate results of Oberndorfer (2009) on European stock markets and afterward Masih *et al.* (2011), and Basher *et al.* (2012) on emerging markets. The US economic and monetary policy (as represented by broad trade-weighted USD exchange rate, US interest rate and US CPI) results in a significant unrest on international stock markets. Indeed, economic expectations 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 price 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 CPI and interest rate. The corporate default premium has an indirect negative effect on international oil price. Also, Chinese oil gross imports have a negative influence on international oil price. We explain this evidence by the fact that the worldwide demand on oil commodity is associated with corporate risk rating. Tang and Xiong (2012) stated that as a result of the financialization process, oil price has become increasingly correlated with futures price 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

Variables	Direct Effects Coef. (SD)	Indirect effects Coef. (SD)	Total effects Coef. (SD)
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	−2,874.573 (316.657)***	–	–
Log-likelihood	−12,441.742		
χ^2	325.01 (0.0000)		
No. of obs.	250	250	250

Table I.
Estimation results

Notes: *,**,***Indicate that coefficients are statistically significant at 10, 5 and 1 percent levels, respectively

exchange rate affects oil price via demand and supply on international markets and support recent results of 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 price on international markets is positively and significantly affected by oil price and USD. Changes in stock market prices have a negative effect on gold price. This evidence is very plausible and support findings of Sumner *et al.* (2010) and Gaur Bansal (2010) that falling stock markets results in rising gold price. The current results confirm our theoretical analysis and the previous literature. We cite *inter alia*, Le and Chang (2012). The indirect effects confirm the close tie between gold and oil and USD. Gold price is also indirectly and significantly affected by US CPI, US interest rates, oil futures price and Chinese oil gross imports. Regarding the total effects, gold price is concerned by changes in oil price, stock markets, USD exchange rate, US inflation and US interest rate, oil futures price and Chinese oil gross imports. It is important to note here that US oil gross imports and default premium have slight effects on gold price but the informational content of gold price highlights well the 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 CPI. 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), and recently Bekaert *et al.* (2013). The USD is also indirectly and significantly affected by US CPI, oil futures price and Chinese oil imports. The total effects confirm the negative and significant effects of oil price, gold and stock market prices (Bodenstein *et al.*, 2011; Allegret *et al.*, 2014), and effects of the other additional controls.

Figure 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.

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 paper is to highlight the interdependencies between all the markets 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, USD and stock prices. Indeed, we found that oil price is significantly affected by stock markets, gold and USD. Oil price is also affected by oil futures price and by Chinese oil gross imports. Gold price is concerned by changes in oil, USD and stock markets but slightly depend on US oil imports and default premium. The USD exchange rate is significantly affected by oil price, gold price and stock market prices. The USD is also negatively affected by the US CPI. 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 hedging, which intensifies direct and indirect ties between all the markets and thus confirms 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

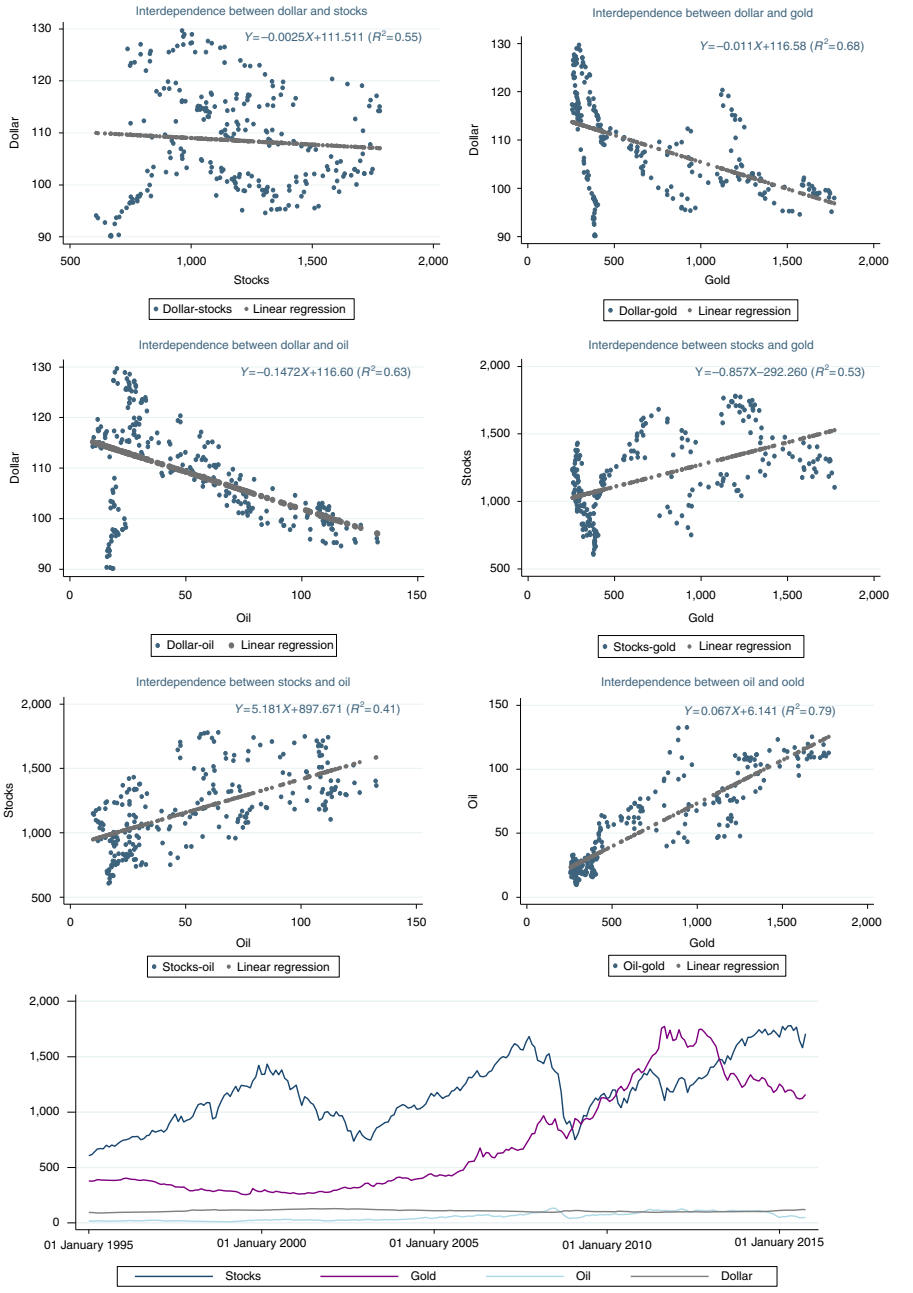

Figure 2.
Bilateral interdependencies between the relevant endogenous variables

dependency on foreign oil, the current Chinese' slowed economy and the continued struggles of emerging markets along with the trend to softer world economy in addition to the current strategic and geopolitical events move all forward these challenges to be drivers over crude oil, gold and US dollar beyond this decade.

Notes

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.
2. Statistical properties of the data and pairwise correlations between all variables are not presented here to save space but are ready to be presented upon request.
3. 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.

References

Akram, Q.F. (2009), "Commodity prices, interest rates and the dollar", *Energy Economics*, Vol. 31 No. 6, pp. 838-851.

Allegret, J.P., Mignon, V. and Sallenave, A. (2014), "Oil price shocks and global imbalances: lessons from a model with trade and financial interdependencies", *Economic Modelling*, Vol. 49 No. C, pp. 232-247.

Arouri, M.E.H., Jouini, J. and Nguyen, D. (2012), "On the impacts of oil price fluctuations on European equity markets: volatility spillover and hedging effectiveness", *Energy Economics*, Vol. 34 No. 2, pp. 611-617.

Backus, D.K. and Mario, J.C. (2000), "Oil prices and the terms of trade", *Journal of International Economics*, Vol. 50 No. 1, pp. 185-213.

Basher, S.A. and Sadorsky, P. (2006), "Oil price risk and emerging stock markets", *Global Finance Journal*, Vol. 17 No. 2, pp. 224-251.

Basher, S.A., Haug, A.A. and Sadorsky, P. (2012), "Oil prices, exchange rates and emerging stock markets", *Energy Economics*, Vol. 34 No. 1, pp. 227-240.

Baur, D. and McDermott, T. (2010), "Is gold a safe haven? International evidence", *Journal of Banking and Finance*, Vol. 34 No. 8, pp. 1886-1898.

Beckmann, J. and Czudaj, R. (2013), "Is there a homogeneous causality pattern between oil prices and currencies of oil importers and exporters?", *Energy Economics*, Vol. 40 No. C, pp. 665-678.

Bekaert, G., Hoerova, M. and Duca, M.L. (2013), "Risk, uncertainty and monetary policy", *Journal of Monetary Economics*, Vol. 60 No. 7, pp. 771-788.

Bénassy-Quéré, A., Mignon, V. and Penot, A. (2007), "China and the relationship between the oil price and the dollar", *Energy Policy*, Vol. 35 No. 11, pp. 5795-5805.

Bodenstein, M., Erceg, C.J. and Guerrieri, L. (2011), "Oil shocks and external adjustment", *Journal of International Economics*, Vol. 83 No. 2, pp. 168-184.

Caballero, J.R., Farhi, E. and Gourinchas, P.O. (2008), "Financial crash, commodity prices, and global imbalances", Working Paper No. 14521, National Bureau of Economic Research, Cambridge, MA, December.

Caporale, M., Pittis, N. and Spagnolo, N. (2002), "Testing for causality-in-variance: an application to the east Asian markets", *International Journal of Finance and Economics*, Vol. 7 No. 3, pp. 235-245.

Chkili, W., Hammoudeh, S. and Nguyen, D.K. (2014), "Volatility forecasting and risk management for commodity markets in the presence of asymmetry and long memory", *Energy Economics*, Vol. 41 No. C, pp. 1-18.

De Schryder, S. and Peersman, G. (2015), "The US dollar exchange rate and the demand for oil", *The Energy Journal*, Vol. 36 No. 3, pp. 1-18.

Dornbusch, R. and Fischer, S. (1980), "Exchange rates and the current account", *American Economic Review*, Vol. 70 No. 5, pp. 960-971.

Ewing, B.T. and Malik, F. (2013), "Volatility transmission between gold and oil futures under structural breaks", *International Review of Economics and Finance*, Vol. 25 No. C, pp. 113-121.

Fratzscher, M. (2009), "What explains global exchange rate movements during the financial crisis?", *Journal of International Money and Finance*, Vol. 28 No. 8, pp. 1390-1407.

Fratzscher, M., Schneider, D. and Robays, I.V. (2014), "Oil prices, exchange rates and asset prices", Working Paper No. 1689, European Central Bank, Frankfurt am Main, July.

Gaur, A. and Bansal, M. (2010), "A comparative study of gold price movements in indian and global markets", *Indian Journal of Finance*, Vol. 4 No. 2, pp. 32-37.

Gilmore, C.G., McManus, M.G., Sharma, R. and Tezel, A. (2009), "The dynamics of gold prices, gold mining stock prices and stock market prices comovements", *Research in Applied Economics*, Vol. 1 No. 1, pp. 1-19.

Golub, S. (1983), "Oil prices and exchange rates", *The Economic Journal*, Vol. 93 No. 371, pp. 576-593.

Granger, C.W.J., Huang, B.N. and Yang, C.W. (2000), "A bivariate causality between stock prices and exchange rates: evidence from recent Asianflu", *The Quarterly Review of Economics and Finance*, Vol. 40 No. 3, pp. 337-354.

Jones, C.M. and Kaul, G. (1996), "Oil and the stock market", *Journal of Finance*, Vol. 51 No. 2, pp. 463-491.

Kang, S.H. and Yoon, S.M. (2013), "Revisited return and volatility spillover effect in Korea", *Korea and the World Economy*, Vol. 14 No. 1, pp. 121-145.

Kilian, L. (2009), "Not all oil price shocks are alike: disentangling demand and supply shocks in the crude oil market", *American Economic Review*, Vol. 99 No. 3, pp. 1053-1069.

Kilian, L. and Park, C. (2009), "The impact of oil price shocks on the US stock market", *International Economic Review*, Vol. 50 No. 4, pp. 1267-1287.

Krugman, P. (1983), "Oil shocks and exchange rate dynamics", in Frenkel, J.A. (Ed.), *Exchange Rates and International Macroeconomics*, University of Chicago Press, Chicago, IL, pp. 259-284.

Le, T.H. and Chang, Y. (2012), "Oil price shocks and gold returns", *International Economics*, Vol. 131 No. 3, pp. 71-104.

Lombardi, M.J. and Robays, I.V. (2011), "Do financial investors destabilize the oil price?", Working Paper No. 1346, European Central Bank, Frankfurt am Main, June.

Masih, R., Peters, S. and De Mello, L. (2011), "Oil price volatility and stock price fluctuations in an emerging market: evidence from South Korea", *Energy Economics*, Vol. 33 No. 5, pp. 975-986.

Melvin, M. and Sultan, J. (1990), "South African political unrest, oil prices, and the time varying risk premium in the gold futures market", *Journal of Futures Markets*, Vol. 10 No. 2, pp. 103-111.

Miller, J.I. and Ratti, R.A. (2009), "Crude oil and stock markets: stability, instability, and bubbles", *Energy Economics*, Vol. 31 No. 4, pp. 559-568.

Mollick, A.V. and Assefa, T.A. (2013), "US stock returns and oil prices: the tale from daily data and the 2008-2009 financial crisis", *Energy Economics*, Vol. 36 No. C, pp. 1-18.

Narayan, P.K., Narayan, S. and Zheng, X. (2010), "Gold and oil futures markets: are markets efficient?", *Applied Energy*, Vol. 87 No. 10, pp. 3299-3303.

Oberndorfer, U. (2009), "Energy prices, volatility, and the stock market: evidence from the Eurozone", *Energy Policy*, Vol. 37 No. 12, pp. 5787-5795.

Olugbenga, A.A. (2012), "Exchange rate volatility and stock market behaviour: the Nigerian experience", *European Journal of Business and Management*, Vol. 4 No. 5, pp. 31-39.

Reboredo, J.C. (2013), "Is gold a hedge or safe haven against oil price movements?", *Resources Policy*, Vol. 38 No. 2, pp. 130-137.

Robays, V.I. (2016), "Macroeconomic uncertainty and oil price volatility", *Oxford Bulletin of Economics and Statistics*, Vol. 68 No. 5, pp. 671-693.

Sadorsky, P. (2000), "The empirical relationship between energy futures prices and exchange rates", *Energy Economics*, Vol. 22 No. 2, pp. 253-266.

Sekmen, F. (2011), "Exchange rate volatility and stock returns for the US", *African Journal of Business Management*, Vol. 5 No. 22, pp. 9659-9664.

Sumner, S., Johnson, R. and Soenen, L. (2010), "Spillover effects between gold, stocks, and bonds", *Journal of Centrum Cathedra*, Vol. 3 No. 2, pp. 106-120.

Tang, K. and Xiong, W. (2012), "Index investment and the financialization of commodities", *Financial Analysts Journal*, Vol. 68 No. 6, pp. 54-74.

Vivian, A. and Wohar, M.E. (2012), "Commodity volatility breaks", *Journal of International Financial Market, Institution and Money*, Vol. 22 No. 2, pp. 395-422.

Wang, M.L., Wang, C.P. and Huang, T.Y. (2010), "Relationships among oil price, gold price, exchange rate and international stock markets", *International Research Journal of Finance and Economics*, Vol. 47, pp. 82-91.

Wang, Y.S. and Chueh, Y.L. (2013), "Dynamic transmission effects between the interest rate, the US dollar, and gold and crude oil prices", *Economic Modelling*, Vol. 30 No. C, pp. 792-798.

Yau, H.Y. and Nieh, C.C. (2006), "Interrelationships among stock prices of Taiwan and Japan and NTD/Yen exchange rate", *Journal of Asian Economics*, Vol. 17 No. 3, pp. 535-552.

Yousefi, A. and Wirjanto, T.S. (2003), "The empirical role of the exchange rate on the crude-oil price formation", *Energy Economics*, Vol. 26 No. 5, pp. 783-799.

Yousefi, A. and Wirjanto, T.S. (2005), "A stylized exchange rate pass-through model of crude oil price formation", *OPEC Energy Review*, Vol. 29 No. 3, pp. 177-197.

Zhang, Y.J. and Wei, M.Y. (2010), "The crude oil market and the gold market: evidence for cointegration, causality and price discovery", *Resources Policy*, Vol. 35 No. 3, pp. 168-177.

Further reading

El-Sharif, I., Brown, D., Burton, B., Nixon, B. and Russell, A. (2005), "Evidence on the nature and extent of the relationship between oil prices and equity values in the UK", *Energy Economics*, Vol. 27 No. 6, pp. 819-830.

Fattahi, S., Sohaili, K. and Amirkhani, M. (2015), "Examination of the relationship among stock, gold and foreign exchange markets: copula functions approach", *International Journal of Applied Business and Economic Research*, Vol. 13 No. 4, pp. 2109-2117.

Filis, G., Degiannakis, S. and Floros, C. (2011), "Dynamic correlation between stock market and oil prices: the case of oil-importing and oil exporting countries", *International Review of Financial Analysis*, Vol. 20 No. 23, pp. 152-164.

Hammoudeh, S., Dibooglu, S. and Aleisa, E. (2004), "Relationships among US oil prices and oil industry equity indices", *International Review of Economics and Finance*, Vol. 13 No. 4, pp. 427-453.

Sadorsky, P. (1999), "Oil price shocks and stock market activity", *Energy Economics*, Vol. 21 No. 5, pp. 449-469.

Corresponding author
Aymen Ben Rejeb can be contacted at: benredjeb_aymen@yahoo.fr