THE IMPACT OF FINANCIAL CRISES ON COMOVEMENTS BETWEEN COMMODITY FUTURES AND EQUITY PRICES: EVIDENCE FROM CRUDE OIL AND GOLD MARKETS

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ABSTRACT

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Return correlations between asset classes have important implications for portfolio diversification. From hedging perspective, it is crucial to examine how the co-movements between asset classes evolve in periods of financial turmoil. This Master's thesis investigates the impacts of stock market crises on correlations between commodity futures and equity returns in the U.S market by providing evidence especially from crude oil and gold markets. The econometric modelling relies on the generalized diagonal DCC GARCH model proposed by Cappiello, Engle and Sheppard in 2006. The empirical analysis compares the evolution of conditional correlations between aggregate U.S equities and energy sector equities. Moreover, this thesis examines, whether gold and crude oil futures are attractive instruments for risk minimizing cross-market hedging for equity investments.

The empirical results indicate that correlations change significantly during periods of stock market crises. Dynamic conditional correlations show that the correlation between crude oil futures and aggregate U.S equities increases in periods of financial turmoil, whereas in case of gold futures the correlation becomes negative, which supports the safe haven hypothesis of gold. In case of energy sector equities, the evolution of correlations differs significantly compared to aggregate U.S equities. In addition, it is worth noting that the volatility of correlations is high, which does not support using crude oil and gold futures in cross-market hedging in normal times. When scrutinizing the dynamic hedge ratios, gold futures seem to be more attractive hedging instruments against aggregate U.S equities in periods of stock market sell-offs. As for energy sector equities, the dynamics of hedge ratios supports using neither crude oil nor gold futures in cross-market hedging during stock market crises.

Key words
financialization of commodity markets, dynamic conditional correlations, hedge ratios, gold markets, crude oil markets

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Omaisuusluokkien välisillä korrelaatioilla on tärkeä rooli sijoitussalkun hajautusta ajatellen. Omaisuuslajien suojauksen kannalta erityisen tärkeää on tutkia, miten eri omaisuusluokat korreloivat kriisiperiodien aikana. Tässä Pro-Gradu -tutkielmassa tarkastellaan osakemarkkinakriisien vaikutusta hyödykefutuurien ja osakemarkkinatuottojen välisiin korrelaatioihin USA:n markkinoilla erityisesti raakaöljyn ja kullan osalta. Korrelaatioiden mallintamisessa hyödynnetään Cappiellon, Englen ja Sheppardin vuonna 2006 ehdottamaa yleistettyä diagonaalimuotoista DCC GARCH -mallia. Tutkimuksessa verrataan ehdollisten korrelaatioiden kehitystä erikseen USA:n osakemarkkinoiden yleisindeksin ja energiasektorin osakkeiden välillä. Lisäksi tutkimuksessa tarkastellaan, onko kulta- ja öljyfutuureja mielekästä käyttää suojausinstrumentteina osakemarkkinasijoitukseen liittyvän riskin minimoimiseksi.

Empiirisen tutkimuksen tulokset osoittavat, että korrelaatiot muuttuvat merkittävästi osakemarkkinakriisien aikana. Dynaamiset ehdolliset korrelaatiot indikoivat, että öljyfutuuri- ja USA:n osakemarkkinatuottojen välinen korrelaatio kasvaa kriisien aikana, kun taas kullan osalta korrelaatio painuu negatiiviseksi puoltaen kullan turvasatama hypoteesia. Energiaosakkeiden kohdalla korrelaatioiden dynamiikka eroaa merkittävästi yleisosakkeisiin verrattuna. Lisäksi huomioitavaa on, että korrelaatioiden volatiilisuus on korkea, mikä ei tee kulta- ja öljyfutuurien käyttämisestä ristiinsuojaamisessa mielekästä normaaliaikoina. Suojausasteiden valossa kultafutuurit näyttäisivät olevan öljyfutuureja mielekkäämpi suojausinstrumentti osakemarkkinakriisien aikana yleisindeksin kohdalla. Energiaosakkeiden osalta suojausasteiden dynamiikka ei puolla öljy- ja kultafutuurien käyttämistä ristiinsuojauksessa osakemarkkinakriisien aikana.

Avainsanat
hyödykemarkkinoiden sijoittajavetoistuminen, dynaamiset ehdollinen korrelaatio, suojausaste, kultamarkkinat, raakaöljymarkkinat

Säilytyspaikka Jyväskylän yliopiston kirjasto

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1 INTRODUCTION

1.1 Motivation of the topic

Traditionally stocks and bonds have played a major role in investment portfolios, whereas commodities have been used for industrial and consumption purposes, and hence, they have been segmented outside the traditional asset classes. However, commodity markets experienced a significant change during the beginning of 2000's as financial institutions introduced commodity-linked investment products to provide investors a possibility to reap the portfolio diversification benefits from commodities. This has also been reported by numerous research papers (see, e.g Gorton and Rouwenhorst, 2006). Nowadays commodities are considered as an alternative asset class, which many institutional investors, such as pension funds, hedge funds and insurance companies, hold in their portfolios. Based on the empirical results on the portfolio diversification benefits of commodities and low performance of stocks and bonds at the beginning of 2000's, institutional index-investors and hedge funds have emerged as one of the major players in commodity markets. At the same time, commodity prices have skyrocketed, peaking just before the outbreak of global financial crisis in 2008. The radical increase in commodity prices initiated speculation on whether the financial investors drive commodity prices. For example, the Managing Member of Masters Capital Management, Michael Masters (2008), expressed his concern in his testimony to the U.S senate that speculative trading of financial investors and hedge funds in commodity derivatives markets has caused a bubble in commodity prices and increased their price volatility. Thus, from a pricing perspective, the emergence of financial investors could imply that alongside with fundamentals, the financial motives have become one of the main determinants of commodity prices. The literature has named this phenomenon as the financialization of commodity markets.

Understanding the evolution of co-movements between different asset classes is crucial in many portfolio and risk management assignments in financial markets. For example, when estimating the variance-covariance matrixes for calculating optimal asset allocations, it is important to understand how correlations between asset classes evolve over time. From hedging perspective, it is crucial that the correlation between the asset classes remains low especially in periods of financial turmoil. Hence, it is essential to examine time-varying co-moments between asset class returns, especially during financial crises when the portfolio diversification benefits of asset classes are needed the most. In addition, the valuation of the most sophisticated structured products and exotic options, such as basket options, relies on the correlation between underlying assets. Thus, understanding time-varying correlations between different asset classes helps to understand the pricing of these products in periods of financial crises.

The emergence of institutional investors in commodity markets has introduced more intensive cross market linkages between commodities and equities than previously discovered. The empirical evidence has shown that after the outbreak of Global financial crisis in late 2008 the correlations between commodity and equity returns increased drastically, whereas before the crisis these assets were typically uncorrelated (see, e.g. Creti et. al., 2013). In addition, recent empirical literature has provided evidence that the correlations across commodities have increased starting from 2004 (see e.g, Tang & Xiong, 2012).

1.2 Research questions

In this Master's thesis, I will examine how the correlations between commodity futures and stock market returns evolve in periods of financial turmoil by providing evidence from crude oil and gold futures markets. Crude oil and gold are the main strategic commodities, which investors and financial economists follow on a daily basis. The strategic importance of these commodities makes them interesting commodities to analyse their dependence with respect to equities.

The main difference between crude oil and gold is that crude oil can be regarded mainly as a consumption commodity, whose price depends on global demand and supply. It is worth noting that the daily spot price of crude oil storages is based on the price of crude oil futures. In the global markets crude oil is traded with futures contracts, whereas the spot price of crude oil is actually the price for the extra oil sold daily. Thus, it is more relevant to use the prices of futures contracts in this study. Alongside industrial demand for jewelleries, speculative demand is one of the main factors affecting the price of gold. In addition, recent empirical research has provided evidence that gold provides a safe haven against stock market crashes (see, e.g., Junttila & Raatikainen, 2017 and references therein). Based on this evidence, I will examine whether this safe haven effect is observable also in time-varying correlations. As for crude oil, empirical literature has reported a jump in the correlation after the Global financial crisis in 2008. By extending the sample size to cover the period to 2016, it is possible to study how these correlations evolve in the zero interest rate environment. Zero interest rate environment is particularly interesting, because low interest rates induce a decline in convenience yields of physical commodities and makes commodity trading with financial assets more attractive than physical trading (see, e.g Kolodziej et. al., 2014). In addition, I hypothesize that the zero-interest rate environment makes alternative asset classes, such as commodities, more attractive for investors, because traditional fixed income instruments, such as bonds, do not provide yields at all basically.

Unlike previous research, I extend the correlation analysis by including the energy sector equities in the analysis separately. In the correlation between crude oil futures and equities, theoretically there should be a positive dependence between these assets, since energy sector equities usually benefit from higher oil prices. As for gold futures, I will examine whether the safe haven effects can also be identified in case of energy sector equities in terms of time-varying correlation.

Finally, I will provide implications for cross-market hedging by examining how crude oil and gold futures can be used to hedge against stock market investments. This analysis will be conducted separately for aggregate U.S equities and U.S energy sector equities. It is especially important to scrutinize the hedge ratios in periods of stock market sell-offs, when hedging is needed the most. This analysis is carried out by calculating dynamic hedge ratios, which show how investors should hedge their stock market positions in periods of financial turmoil and normal times.

1.3 Main findings and structure

The results of the empirical analysis show that time-varying correlations differ significantly for crude oil and gold futures. In periods of stock-market sell-offs crude oil futures and S&P 500 total returns become more related, whereas in case of gold futures the correlation becomes negative, highlighting the safe haven properties of gold futures. Hence, because of negative correlation in periods of financial turmoil, gold futures might be more attractive instruments in cross-market hedging compared to crude oil futures. Following the discussion about the increased correlation between crude oil futures and equity returns after the Global financial crisis, the empirical analysis also shows that the correlation has stayed higher since the crisis. When it comes to energy sector equities, since 2004 the crude oil futures and energy sector equity prices have moved together more than they did previously. One possible explanation is that as a result of financialization of commodity markets the cross-market linkage between crude oil and energy sector equities has become stronger. Hence, from hedging perspective crude oil futures may not attractive instruments to minimize the risk in U.S energy sector equity investments. As for the correlation between gold futures and energy sector equity retuns, the results do not indicate that gold futures would provide a safe haven against energy sector equities in periods of financial distress. Because of contradictory results during periods of stock market crises, gold futures may not be reliable hedging instruments against energy sector equities.

The remainder of this thesis is organized as follows. Chapter 2 briefly introduces econometric techniques, which have been used in previous literature to model co-movements between commodities and stock markets. Chapter 3 presents the concept of financialization of commodity markets by discussing the subject in the light of the previous literature. Chapter 4 reviews the previous literature on crude oil and gold markets by discussing how these markets correlate with stock markets in periods stock market sell-offs. Chapter 5 reports empirical analysis of this thesis and chapter 6 concludes the remarks.

2 ECONOMETRIC MODELLING OF DYNAMIC COMOVEMENTS IN FINANCIAL MARKETS

Before discussing the financialization of commodity markets, it is important to get familiarized with econometric modelling techniques that are used in the empirical literature regarding the subject. The techniques, which are discussed in this chapter are especially used for modelling co-movements between commodity prices and stock market prices. Previous literature has often relied on modelling time-varying conditional correlations when examining dynamic relationships between different assets and markets. Modelling dynamic conditional correlations is also crucial in many tasks in the financial markets. For example, understanding the dynamics in the time-varying correlations between different asset classes is important in implementing sophisticated portfolio diversification strategies. Moreover, in risk management modelling dynamic correlations enables calculating dynamic minimum variance hedge ratios. In this chapter, the various ways of modelling time varying conditional correlations are introduced. However, the main focus of this chapter is on the dynamic conditional correlation (DCC) GARCH with its extensions. Moreover, the model Silvennoinen and Teräsvirta (2008) is briefly discussed in this chapter, because is provides an alternative view of modelling dynamic correlations and covariances.

Before going to the econometric modelling techniques of time-varying conditional correlations, the concept of conditional correlation is important to explain. For example, according to Engle (2002) conditional correlations are determined based on the information known during the previous period. Following the formulation of Engle, the conditional correlation between two random variables r_1 and r_2 at time t can be expressed as follows:

$$\rho_{12,t} = \frac{E_{t-1}\,(r_{1,t}r_{2,t})}{\sqrt{E_{t-1}(r_{1,t}^2)E_{t-1}(r_{1,t}^2)}} \tag{1}$$

, where $E_{t-1}(\bullet)$ denotes the conditional expectation operator during time period t-1. Conditional correlation at time t is simply calculated dividing conditional covariance of returns $r_{1,t}$ and $r_{2,t}$ by the product of their conditional standard deviations of these returns.

2.1 Dynamic conditional correlation model

Unlike the constant conditional correlation model proposed by Bollerslev (1990), the DCC-GARCH model enables the investigation of time-varying conditional correlations. The standard version of DCC-GARCH model of Engle (2002) is built on the following estimation procedure. Let's assume r_t to be a k x 1 vector of conditional returns. DCC GARCH is based on the assumption that the conditional returns are normally distributed with zero ean and time-varying variance-covariance matrix H_t i.e $r_t|\xi_{t-1} \sim N(0, H_t)$, where ξ_{t-1} denotes the information set at time t-1. DCC GARCH model is relies on the assumption that the time-varying variance covariance matrix can be decomposed as follows:

$$H_t = D_t P_t D_t, \tag{2}$$

where P_t is a time-varying correlation matrix, which contains the conditional correlations and $D_t = diag\left[\sqrt{h_{i,t}^2}\right]$ is k x k diagonal matrix of time-varying conditional standard deviations. The diagonal matrix of time-varying standard deviations can be issued, for example, as a result of estimation of an univariate GARCH (p,q) model proposed by Bollerslev (1986):

$$h_t^2 = \alpha_0 + \sum_{i=1}^{p} \alpha_i \varepsilon_{t-i}^2 + \sum_{i=1}^{q} \beta_i h_{t-i}^2, \tag{3}$$

where h_t^2 denotes time-varying conditional variance. After the estimation of univariate volatility models for each return time-series, the standardized residuals, defined as $\varepsilon_{it} = \frac{r_{it}}{\sqrt{h_{it}}}$ are used to estimate the evolution of the correlation, given by the following equation:

$$Q_t = (1 - \alpha - \beta)\bar{P} + \alpha \varepsilon_{t-1} \varepsilon_{t-1}' + \beta Q_{t-1}, \tag{4}$$

where $\bar{P} = E[\varepsilon_{t-1} \varepsilon_{t-1}']$ is the unconditional correlation matrix of standardized residuals. In order to ensure the mean reversion of the model, the condition $\alpha + \beta < 1$ must hold. Now the time-varying correlation matrix P_t can be decomposed as follows:

$$P_t = diag\{Q_t\}^{-1} Q_t diag\{Q_t\}^{-1}, \tag{5}$$

where $diag\{Q_t\}^{-1}$ is an inverted diagonal matrix containing the square root of diagonal elements of Q_t:

$$diag\{Q_t\}^{-1} = \begin{bmatrix} 1/\sqrt{q_{11t}} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & 1/\sqrt{q_{nnt}} \end{bmatrix} \tag{6}$$

Because of the normality assumption, the parameters of the model can now be estimated using a maximum likelihood estimation. Parameters of the model can be estimated based on the following likelihood function:

$$L = -\frac{1}{2}\sum_{t=1}^{T}(nlog(2\pi) + log|H_t| + r_t' H_t^{-1} r_t)$$
$$= -\frac{1}{2}\sum_{t=1}^{T}(nlog(2\pi) + 2\log|D_t| + r_t' D_t^{-1} D_t^{-1} r_t - \varepsilon_t'\varepsilon_t + log|R_t| + \varepsilon_t' R_t^{-1}\varepsilon_t) \tag{7}$$

Finally, following the definition of conditional correlation, specified in Equation (1), the time-varying conditional correlations are calculated using the following equation:

$$\rho_{i,j,t} = \frac{q_{i,j,t}}{\sqrt{q_{ii,t}q_{jj,t}}}, \tag{8}$$

where $q_{i,j,t}$ is the covariance between asset returns i and j at time t and $q_{ii,t}$ and $q_{jj,t}$ are the diagonal elements in the variance-covariance matrix Q_t, that is, they are the conditional variance estimates of i and j at time t.

Cappiello, Engle and Shephard (2006) note that time varying risk premia may induce asymmetric response in correlations between returns of different assets. According to Capiello, Engle and Shephard, the theoretical justification behind conditional asymmetries in correlations relies on the idea that negative shock in returns of any pair of stocks will increase the variances of these stocks. In CAPM world, if betas of these stocks do not change, then the covariance between this pair of stocks will increase. Correspondingly, if idiosyncratic variances do change, then the negative shocks than after positive shocks correlation will increase. Thus, the correlations are expected to be higher after negative shocks than after positive shocks.

To introduce conditional asymmetries in correlations when modelling dynamic conditional correlations, Capiello, Engle and Shephard proposed asymmetric generalized DCC GARCH (AG-DCC) model, which captures the asymmetric news impacts in correlations. In case of AG-DCC GARCH model, the evolution of dynamic correlation is estimated the following process:

$$Q_t = (\bar{P} - A'\bar{P}A - B'\bar{P}B - G'\bar{N}G) + A'\varepsilon_{t-1}\varepsilon_{t-1}'A + G'n_{t-1}n_{t-1}'G + B'Q_{t-1}B \tag{9}$$

In the equation above A, B and G denote k x k parameter matrices. The effect of negative shocks on correlations is captured by the variable n_t, which can be written as a Hadamard product of an indicator function and standardized residuals ε_t: $n_t = I[\varepsilon_t < 0] \circ \varepsilon_t$, where $I[\varepsilon_t < 0]$ denotes a k x 1 indicator function, which takes on value 1 if $\varepsilon_t < 0$ and 0 otherwise. The parameter $\bar{N}$ denotes the unconditional correlation matrix of standardized residuals, which take negative values.

Capiello, Engle and Shephard also show, how the special cases of AG-DCC GARCH model can be obtained by restricting the parameter values in the model. In case of asymmetric DCC (A-DCC) model, the parameter matrices A, B and G are replaced by scalars, which reduces the evolution of of dynamic correlations to:

$$Q_t = (\bar{P} - a^2\bar{P} - b^2\bar{P} - g^2\bar{N}) + a^2\varepsilon_{t-1}\varepsilon'_{t-1} + g^2 n_{t-1}n'_{t-1} + b^2 Q_{t-1} \qquad (10)$$

Correspondingly the conditional asymmetries in correlations can be erased from the model by setting G=0. In this case, the generalized DCC model can be expressed as follows:

$$Q_t = (\bar{P} - A'\bar{P}A - B'\bar{P}B) + A'\varepsilon_{t-1}\varepsilon'_{t-1}A + B'Q_{t-1}B. \qquad (11)$$

The last modification of AG-DCC model, proposed by Cappiello, Engle and Shephard, restricts the parameter matrices to be diagonal matrices. In this case, the dynamic correlation process can be written as follows:

$$Q_t = \bar{P}(ii' - aa' - bb') - \bar{N} \circ gg' + aa' \circ \varepsilon_{t-1}\varepsilon_{t-1} + gg' \circ n_{t-1}n_{t-1} + bb' \circ Q_{t-1}. \qquad (12)$$

In equation above, i denotes the vector of ones and a, b and g denote the vectors, which contain the diagonal elements of the matrices A, B and G.

2.2 Conditional correlation as a smooth transition process

Silvennoinen and Teräsvirta (2008) proposed an alternative way of modelling the dynamic conditional correlations in the high frequency financial market return data. The model, which they introduced is called Smooth Transition Conditional Correlation (STCC) GARCH model. The STCC GARCH model enables modelling the dynamic conditional correlations as a smooth transition process between two extreme states of constant correlations. The transition process is expressed as a function of transition variable. Silvennnoinen and Teräsvirta formulated the evolution of conditional correlation P_t as follows:

$$P_t = (1 - G_t)P_{(1)} + G_t P_{(2)}, \qquad (13)$$

where $P_{(1)}$ and $P_{(2)}$ denote the two correlation matrices in extreme states (1) and (2). G_t denotes a logistic transition function, which is defined as follows:

$$G_t = \left(1 + e^{-\gamma(s_t - c)}\right)^{-1}, \qquad \gamma > 0, \qquad (14)$$

where s_t denotes the transition variable and c is the location of transition. The speed of transition is determined by the parameter γ. Thus, alongside investigation of correlation dynamics, the STCC-GARCH enables the determination of how abrupt are the changes in conditional correlations. The values of transition function are bounded between 0 and 1. If the transition variable is defined the calendar time, $s_t = t/T$, the model is called the Time-Varying Smooth Transition Conditional Correlation GARCH model.

An extension to the STCC-GARCH model allows conditional correlations to vary as a function of two transition variables. The Double Smooth Transition Conditional Correlation (DSTCC-) GARCH model, introduced by Silvennoinen and Teräsvirta (2008) imposes the time-varying correlation structure through the following dynamic process:

$$P_t = (1 - G_{2t})\left((1 - G_{1t})P_{(11)} + G_{1t}P_{(21)}\right) + G_{2t}\left((1 - G_{1t})P_{(12)} + G_{1t}P_{(22)}\right) \qquad (15)$$

As in case of STCC-GARCH model, the transition functions G_{1t} and G_{2t} are defined by logistic functions. Thus, the correlation matrix is now a convex combination of four extreme states of constant correlation matrices $P_{(11)}$, $P_{(12)}$, $P_{(21)}$ and $P_{(22)}$.

For illustration of the correlation dynamics, let's assume the second transition variable, s_{2t}, to be calendar time. Now the correlation dynamics can be interpreted as follows: at first the correlations vary smoothly between the extreme states $P_{(11)}$ and $P_{(21)}$, defined by the transition variable s_{1t}. As time evolves, the variation in correlation shifts smoothly to range, defined the extreme states in $P_{(12)}$ and $P_{(22)}$.

3 FINANCIALIZATION OF COMMODITY MARKETS

Recent development in the commodity markets has involved the emergence of index investors, which has initiated the process called financialization of commodity markets. This chapter addresses the structural change in the commodity markets by discussing first the emergence of index investors in commodity markets and then reviewing the economic impacts of the financialization in the light of earlier literature. The last topic of this chapter includes discussion about portfolio diversification benefits of commodities relying on the recent empirical research.

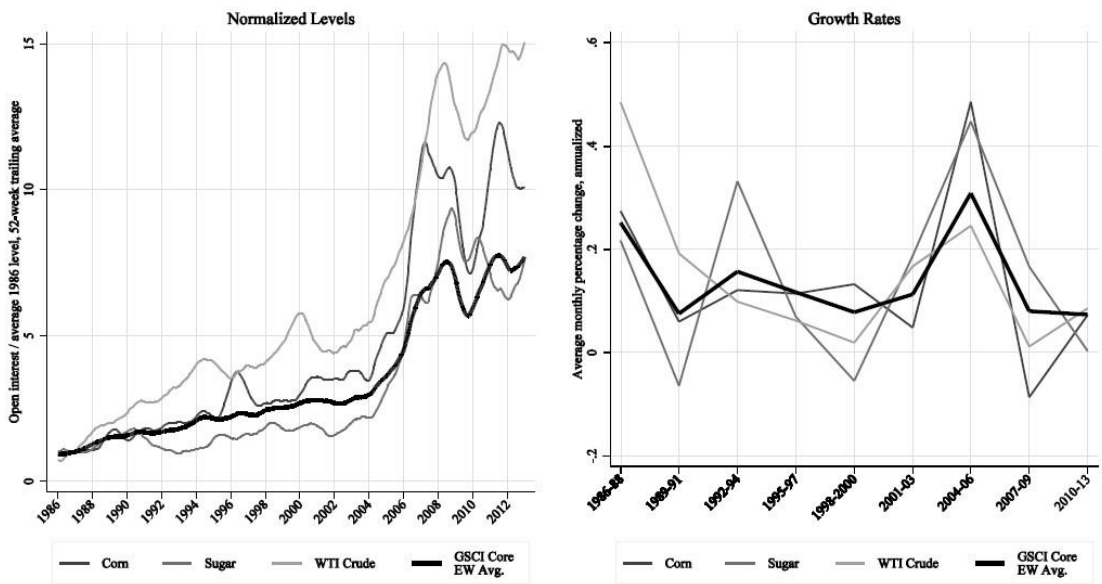
3.1 Emergence of index investors in commodity markets

"The birth of a style is often triggered by good fundamental news about the securities in the style. The style then matures as its good performance recruits new funds, further raising the prices of securities belonging to the style." (Barberis & Schleifer, 2003)

Commodities have traditionally been expected to provide benefits in portfolio diversification, because they usually possess small or even negative correlation with stock or bond market returns. For example, Gorton and Rouwenhorst (2006) constructed an equally-weighted commodity index between July 1959 and December 2004 to provide long-term properties of an investment in commodity futures. The main finding supporting the diversification benefits of commodity futures is that the correlations with stocks and bonds is negative in most time horizons. The correlations were also observed to increase with the holding period. In addition, positive correlation with inflation indicates that commodity futures provide protection against unexpected inflation, whereas the correlation between stocks and bonds is negative. This evidence indicates that compared to commodity futures, traditional asset classes tend to perform worse under unexpected inflation. By comparing statistical figures, Gorton and Rouwenhorst concluded, that stocks are riskier than commodity futures, measured by higher standard deviation of returns. In addition, they observed that commodity futures returns display positive skewness whereas stock returns are negatively skewed. Combining this observation with lower standard deviation, one may conclude that stock returns possess more downside risk compared to commodity futures returns. The results also indicate that measured by average return and Sharpe ratio, historically commodity futures have offered similar returns to the U.S equities. To sum up, the results of Gorton and Rouwenhorst give a strong evidence of portfolio diversification benefits of commodity futures. Similar results are also obtained in many other research papers. For example, the results of Erb and Harvey (2006) indicate that commodity markets were partly segmented outside financial markets, which gives even more support for diversification benefits of commodities.

Following the observed portfolio diversification benefits of commodities, the number of commodity related investment products increased rapidly during the early 2000s. The U.S Commodity Trading Commission (2008) reported that in June 2008 the total OTC and the exchange based commodity index investment activity was USD 200 billion, whereas in 2003 the equivalent activity was USD 15 billion. Figure 1[1], which is retrieved from the working paper of Cheng and Xiong (2013), plots the development of open interest levels of corn, sugar, WTI crude oil and S&P GSCI index. Figure 1 reveals that starting from 2004 open interest levels increased significantly peaking before the outbreak of global financial crisis in 2008. In addition, growth rates indicate that there was a rapid growth in open interest levels in case of all commodities, which suggests higher investment activity in commodity futures market. According to financial literature, the rapid increase of index investors in commodity markets initiated "financialization" process of commodity markets (see, e.g., Tang & Xiong, 2012).

Figure 1 Open interest in commodity markets (Cheng & Xiong, 2013)



[1] The values reported in the figure are calculated as 52-week trailing average and GSCI Core Ev. Avg. index is calculated as equally weighted average of commodities within the Goldman Sachs Commodity Index. In addition, values are normalized to the average open interest during 1986.

3.2 The impacts of commodities financialization process

According to definition, "financialization is understood to mean the vastly expanded role of financial motives, financial markets, financial actors and financial institutions in the operation of domestic and international economies, and in this case, the increasing role in commodities markets" (Falkowski, 2011).

Traditional economic theory suggests that the price formation of a commodity relies on the equilibrium of supply and demand. The commodity supply can be expressed as a function of production. For example, changes in weather conditions, strikes and other breaks in production may lead to fluctuations in commodity prices. In addition, commodity prices are closely related to storage capacity. (see, e.g, Falkowski, 2011) According to Trostle (2008), the price of a physical commodity also depends on other attributes, such as location and physical quality. When speaking about commodity futures prices, the theory of storage suggests that prices are positively related to storage costs and negatively to convenience yields (see e.g Fama & French 1987). Convenience yield can be defined as a benefit from holding commodity, because they might be inputs in the production for other commodities. For example, instead of using financial derivatives, holding physical WTI or Brent oil might be beneficial, because they act as inputs in the refinement process of fuels.

Falkowski (2011) notes that as a result of financialization process, the factors determining commodity prices have changed. Alongside with demand and supply fundamentals, financial factors, such as aggregate risk appetite for financial assets and investment behaviour of diversified commodity index investors and hedge funds are also now main determinants of commodity prices. Could this indicate that the commodity market, which was earlier observed to be segmented outside the financial markets, would be as a result of financialization process more integrated with financial markets. The integration with financial markets could, in turn, indicate decreased benefits from using commodities to enhance portfolio diversification.

Tang and Xiong (2012) studied whether the prices of non-energy commodities have become increasingly correlated with oil prices during the 2000s, which could indicate the financialization process of commodities. Using rolling correlation estimates Tang and Xiong showed that the average correlation of indexed-commodities increased significantly after 2004, whereas the similar increase in correlation of off-index commodities was not detected after 2004. As discussed earlier, index investment increased significantly in commodity markets between 2003 and 2008. Tang and Xiong concluded that because of increased index investment in commodity markets, the prices of non-energy commodity futures have become more correlated with oil prices than before. Moreover, Tang and Xiong found evidence that indexed commodities are more exposed to common shocks, that are driven by investor interest rather than macroeconomic fundamentals. In a nutshell, the evidence of Tang and Xiong suggests that commodity index trading has increased the cross-commodity correlations significantly.

While Tang and Xiong (2012) studied the correlation dynamics between indexed commodities, Silvennoinen and Thorp (2013) tried to find evidence of closer integration between conventional asset classes and commodity futures. Using DSTCC-GARCH model (introduced in the previous chapter) and weekly log returns on 24 commodity futures, Silvennoinen and Thorp searched for the gradual or abrupt changes in correlation dynamics, which might be a result of financialization process. The results of Silvennoinen and Thorp indicate that in many cases the conditional correlation between commodity futures and US stock market index increased between 1990-2009. Typically, the correlation was observed to rise towards 0,5 from correlation levels close to zero during the early 1990s. Especially in case of metals and oil products the integration with the stock markets was observed to be more pronounced than in case of precious metals, (excluding silver) and agricultural products. Interestingly, the results also indicate that correlation between commodity futures and stock market increases as a result of financial shocks. For about half of the pairs, high stock market volatility, measured by VIX index[2], is associated with higher commodity return correlation with stock market returns, which indicates strong financial influences on correlations. To be more specific, the regime switches in correlations driven by VIX index, have become more frequent during the 2000s, when the capital flows from institutional investors into commodity markets increased. Thus, the evidence of Silvennoinen and Thorp suggest that the role of financial motives has become more important in the pricing of commodity futures than before. The results also indicate that, when financial uncertainty increases, the co-movement between commodities and equities becomes stronger. To sum up the results of Silvennoinen and Thorp, it seems that the stronger investor interest in commodities may have created closer integration with equities, which in turn suggests that portfolio diversification benefits of commodities are not as evident as earlier research shows.

As discussed in the previous chapter, DSTCC-GARCH method models the evolution of conditional correlation as smooth transition process between four extreme states of conditional correlation. Previous literature has also employed DCC-GARCH model of Engle (2002) to illustrate the evolution of conditional correlation between commodity markets and equities. Choi and Hommoudeh (2010) used weekly data on Brent oil, WTI oil, copper, gold, silver and S&P 500 index covering time period from January 2, 1990 to May 1, 2006 to identify dynamic conditional correlation between commodity and equity market returns. In addition, they studied time-varying correlations among these strategic commodities. The results show that the correlations among these commodities have increased since 2003, which supports the findings of Tang and Xiong (2012) of the financialization of commodity markets. However, the results do not indicate increasing correlations between commodities and equities during the sample period.

Extending the research of Choi and Hammoudeh, Creti, Joëts and Mignon (2013) used panel data consisting of 25 commodities' spot price series covering

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[2] VIX index measures an expected implied volatility of S&P 500 stock options. It is commonly used to measure investor sentiment in stock markets.

various sectors over the period from January 2000 to November 2011 to investigate the relationship between commodities and equities. Following the research of Choi and Hammoudeh, Creti et al. also employed DCC GARCH method, when modelling time-varying correlations. Firstly, the evolution of correlations shows that they are highly volatile during the entire time period. Secondly, the results support the findings of Choi and Hammoudeh, that the correlation between commodities and equities did not increase after 2004. Instead by extending the time period they show that in many cases the correlation increased during the Global Financial Crisis in 2007-2008, which suggests an increasing integration between commodity and stock markets. In addition, the results show that correlations have remained high after the Global Financial Crisis. This evidence suggests that Global Financial Crisis highlighted the financialization of commodity markets by inducing the structural increase in correlations between commodities and equities.[3] Thus, for index investors this could imply that commodities are not as attractive substitutes to equities as earlier research has shown. Especially the increase in correlations during the Global Financial Crisis in 2008 does not support alleged risk management incentives to use commodities as substitutes for equities during the bear market. To sum up the evidence, it seems that commodity markets are not anymore so segmented outside the financial markets as earlier research has suggested.

While Tang and Xiong (2012) proposed that commodity index trading is one of the main reasons behind increased cross-commodity correlation, Büyüksahin and Robe (2014) studied the reasons behind the increased cross-market linkages between commodities and equities during the global financial crisis in 2008. The evidence of Büyüksahin and Robe shows that cross-market trading has significantly increased during the 2000's. Using a dataset of trader positions in 17 commodity and equity futures markets in the United States, Büyüksahin and Robe tested whether the changes in these trader positions have predictive power on the patterns in cross-market correlations. The findings of Büyüksahin and Robe suggest that the positions of hedge funds, who trade both commodities and equities, have significant predictive power on the cross-market linkages between commodities and equities. On the contrary, they found evidence that the positions of commodity index traders and swap dealers is not related to cross-market correlations. However, the results also indicate that the predictive power of hedge funds' positions becomes weaker in periods of financial market stress.

One important issue yet to be discussed is the economic impact of closer integration of commodities. Relying on this proposition, Tang and Xiong (2012) showed that the volatility of indexed non-energy commodities was higher than the volatility of off-indexed non-energy commodities in 2008. In addition, the results of Tang and Xiong suggest that the difference between volatilities can be partly explained by the increased correlations of indexed commodities with oil, which was earlier concluded to be a result of the financialization process. This evidence supports strongly that the volatility spillovers among commodities are

[3] Exceptions are gold, cocoa and coffee, which are still attractive substitutes to equities, because of adverse price movements compared to the stock market, when equity prices are declining.

partly related to the financialization of commodity markets. Moreover, previous empirical research has shown that volatility spillovers also exist between equities and commodities (see, e.g, Mensi 2013).

On the other hand, index investment in commodity markets could have led to more efficient sharing of commodity price risk as investors and speculators increase liquidity in commodity markets. The more efficient sharing of commodity price risk would mean lower risk premiums and higher prices on average. Higher prices would in turn be beneficial for producers, who sell those commodities. (Tang & Xiong, 2010)

3.3 Theoretical background of co-movements between fundamentally unrelated assets

Traditional asset pricing theory suggests that financial assets are valued based on their expected cash-flows. For example, stocks in the same sector are influenced by common shocks that affect the cash-flows of each stock in this sector, which is reflected by relatively high correlation between the returns of these stocks. Thus, based on asset pricing theory, the increase in co-movement between asset returns should be inherent from the increased co-movement between fundamental cash-flows. As stated earlier, commodities have traditionally displayed low correlation with equities, which indicates that fundamentals driving the prices of commodities and equities are not very closely related to each other. Low correlations are also observed across commodities, which suggests that the pricing fundamentals also vary across commodities. However, because of the financialization of commodity markets correlations among commodities and between equities have increased significantly. At the same time, previous research has not found any changes in fundamental pricing factors affecting cash-flows, which could explain the increased correlation considering traditional theory. This section introduces some theoretical approaches to the co-movements between unrelated assets, which could provide some useful theoretical insights for understanding the effects of financialization process.

Barberis and Schleifer (2003) studied asset prices in an economy, where investors group risky assets into categories (styles), or more commonly speaking into asset classes, and allocate funds among these asset classes depending on their relative performances. In the commodity markets, this would mean that instead of looking commodities at individual levels, investors may prefer to allocate their funds in commodity market indices. Barberis and Schleifer stated that financial innovations are one of the key drivers creating new styles. For instance, if investors find abnormal profits or diversification benefits in some asset class, they include this asset class in their portfolios. Because investors tend to demand assets at the level of an asset class or style, investors trade all securities belonging in the same style at once depending on their relative performance compared to other styles. This means that if one style would display superior past relative performance, investors would demand all securities belonging to this style, which would push up the prices of this style. Based on this statement Barberis and Schleifer concluded that after security is added into a new style, for example into an index, the correlation with the other securities increases even if the relationship between cash-flows remains unchanged. Thus, assets in the same style will be more correlated than the correlation between the underlying cash-flows would indicate. Barberis and Schleifer state that noise trading can be used to explain this excess co-movement between assets in the same asset class or style. According to Barberis and Schleifer noise trading can also induce common factors, which affect the returns of the assets in the same asset class, even when the cash-flows of these assets remain unchanged. Assuming, that noise traders, whose trading is usually based on the market sentiment rather than fundamentals, can affect asset prices, demand coordinated by noise traders towards some asset class can generate price co-movements inside the asset class, which is unrelated to fundamentals. Based on the market sentiment, noise traders buy or sell the securities belonging to some style at once, which changes the prices of these securities together in the same direction. The theory of Barberis and Schleifer is consistent with the increased correlations among commodities. As already discussed, commodities have traditionally displayed portfolio diversification benefits, which have attracted institutional investors in commodity markets. Relying on the theory of Barberis and Schleifer, the increase in correlations among commodities could stem from higher demand towards commodities from institutional investors, who prefer allocating their funds in commodity indexes rather than in individual commodity futures.

The theory of Barberis and Schleifer is useful when explaining rising correlations among commodities after 2004, but it cannot provide explanation, why the correlations between commodities and equities suddenly increased in 2008. The theory of Kyle and Xiong (2001) on cross-market contagion could be useful, when explaining volatility spillovers and increasing correlations during financial crisis. Kyle and Xiong studied financial contagion as a wealth effect in a world with two risky assets and three types of traders. Their theory assumes that traders are divided into long-term investors, noise traders and convergence traders. Long-term investors are value-based investors, who hold both risky assets and rely their investment strategies on the difference between asset prices and their fundamental values. Noise traders invest randomly only in one of the risky assets. Convergence traders use short-term trading strategies by taking an opposite side to noise trading. Convergence traders are assumed to trade based on logarithmic utility function, which implies that convergence traders try to prevent their wealth from dropping to zero by rebalancing their portfolios dynamically. The model assumes that mean returns and variances are functions of the wealth of convergence traders and the positions of noise traders. In this framework contagion happens when convergence traders' wealth decreases because of unfavourable shock in fundamentals. Because of this negative wealth effect, the convergence traders liquidate positions in both risky assets, which increases the correlation across these risky assets and the volatility in both markets.

This theory suggests that the increase in correlations between commodities and equities during Global financial crisis could be inherent from the liquidation of commodity and equity positions during the financial distress. However, the theory of Kyle and Xiong does not provide an explanation, why correlations between commodities and equities have stayed at higher level after the Global Financial Crisis as the results of Creti, Joëts and Mignon (2013) indicate.

3.4 New evidence on the diversification benefits of commodities

The intensified cross-market linkages between commodities and equities have raised doubts, whether the diversification benefits of commodities have deteriorated because of increased capital flows into commodity markets. Following the discussion around the financialization of commodity markets, recent empirical literature has given evidence that portfolio diversification benefits are not as evident as the previous research has alleged.

For example, Daslaki and Skialopoulos (2011) investigated, whether including commodities in portfolios consisting of traditional asset classes is more profitable than using only traditional asset classes. Unlike previous research papers, Daslaki and Skialopoulos considered a more general approach than the traditional mean-variance setting to review portfolio diversification benefits of commodities. They divided investors into mean-variance and non-mean variance investors and also evaluated the out-of-sample performance of optimal portfolios. Using a dataset covering the period from January 1989 to December 2009, Daslaki and Skialopoulos showed that commodities are only beneficial to non-mean-variance investors, when evaluating the performance under in-sample setting. However, the diversification benefits disappear, when the performance is evaluated under out-of-sample setting.

Cheung and Miu (2010) also investigated portfolio diversification benefits of commodities. Using the sample period from January 1970 to December 2005 they studied the diversification benefits of commodities separately in low and high return environments. Interestingly the results of their research suggest that adding commodities in portfolios increases the risk-adjusted return of the portfolio in a high return environment, but those benefits are not found to be statistically significant in a low return environment. In addition, the correlations between commodities and equities were observed to be systematically higher in low return environment, which is in line with the discussion earlier in this chapter. Thus, the results suggest that adding commodities in portfolios might be beneficial during the times of increasing commodity prices. Otherwise using commodities as substitutes for traditional asset classes might not be as beneficial as alleged in the earlier literature. Unfortunately, the results of Cheung and Miu also show that high return environments of commodity futures are infrequent. Consequently, the performance enhancing attributes of commodity futures seem to stem from infrequent high return periods, when correlations with stock markets are lower than during periods of low returns.

Considering the increase in the correlation between commodities and equities, it is evident that the diversification benefits of commodities have deteriorated. As already discussed, investors who trade both commodities and equities, may induce a link between commodity and equity prices. Thus, the emergence of institutional investors may have led to the deterioration of the diversification benefits of commodities.

4 THE RELATIONSHIP BETWEEN CRUDE OIL, GOLD AND STOCK MARKET PRICES

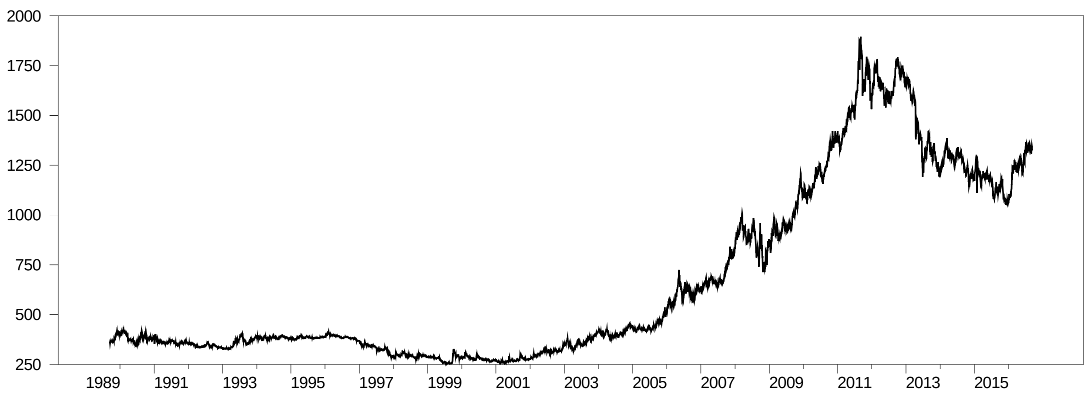
The empirical analysis of this thesis focuses on the examination of co-movements between gold, oil and stock markets during financial crises. Gold and oil are one of the most important strategic commodities, which investors and financial economists follow on daily basis. The main difference between crude oil and gold markets is that crude oil represents consumption commodities, whereas gold is usually regarded as investment commodity This chapter reviews the previous literature on co-movements between gold, crude oil and stock markets.

4.1 Gold markets

Gold has been used in trade for many millennia and it is still considered as an important precious metal in the modern economies. In consumer market the demand for gold arises in the form of jewelleries, whereas in the industry gold is used in technology and dentistry. In addition, central banks, investors and speculators demand gold for asset management purposes and as a store of value. Gold has also been used as a basis for monetary system for many years, which means that currencies were linked to gold at a fixed price. The largest share of the gold demand is in the form of jewelleries, but following the financialization of commodity markets the demand for gold-linked exchange traded products has increased significantly. Today the investment demand for gold accounts for the second largest share of total demand for gold. The supply of gold is sourced from mining and recycled gold. According to the estimates of World Gold Council, the supply from mining accounts for two thirds of total gold supply, whereas recycled gold accounts for the remaining third. (World Gold Council)

Figure 2 below shows the evolution of gold spot price in the U.S from 1989 to 2016. The time series of gold price reveals that there has been a steep increase in the gold price since the beginning of 2000s. For example, between 2003 and 2013 the price of gold increased 382 percent. According to Baur and McDermott (2010) one of the main reasons for a steep increase in the price of gold is the increased investment activity in gold. As discussed in the previous chapter, the number of commodity-linked investment products increased significantly during the beginning of 2000s, which induced the financialization of commodity markets. Empirical research has studied whether this exponential growth in the price of gold between 2002 and 2012 is due to financial speculation. For example, the evidence of Baur and Glover (2015) suggests that the price development in this period can partly be explained by speculative trading in gold markets. In addition, Figure 2 reveals that the price of gold continued to increase reaching its highest price in its' history despite the Global financial crisis and European credit crisis.

Figure 2 Handy & Harman gold bullion spot price ($/Troy Oz) (Source: Datastream)



Traditionally the attraction of gold as a financial asset lies in the empirical evidence of its ability to provide a hedge against inflation and the fluctuations in the value of U.S dollar. For example, using cointegration analysis Ghosh, Lein, MacMillan and Wright (2004) provide evidence that gold can be regarded as a hedge against inflation in the long-run. Capie, Mills and Wood (2005), in turn, show that gold has provided a hedge against the depreciation of US dollar. According to Capie et. al, the main reason for this is that gold is denominated in US dollars and the supply of gold is independent of the changes in the supply of money.

Speaking of the relationship between gold and equities, it has been argued that gold retains its value especially during periods of political or economic uncertainty. Based on this attribute, investors and speculators have usually referred to gold as a safe haven asset. Baur and Lucey (2010) investigated, whether gold is a hedge or safe haven asset against stocks and bonds. To draw a clear distinction between hedge and safe haven assets, Baur and Lucey defined a hedge asset as a security, which is uncorrelated with stocks and bonds on average, whereas safe haven assets are securities, which are uncorrelated or negatively correlated with stocks and bonds in extreme stock or bond market conditions. For example, in times of declining stock prices, the price of safe haven asset would go up, but during bullish market conditions, the correlation between safe haven asset and stock market might be positive. The dataset, which Baur and Lucey used in their analysis, covered a 10-year period from November 30, 1995 until November 30, 2005. The analysis of Baur and Lucey focused on three financial markets with different currencies: United States, the United Kingdom and Germany. Using the data consisting of MSCI stock and bond market indexes and U.S closing gold spot price, Baur and Lucey showed that gold is a safe haven asset for stocks in all three markets used in the analysis, but it only functions for a short period of time[4]. Baur and Lucey also reported gold to be a hedge asset against stocks in the United Kingdom and Germany, so that gold is uncorrelated with stock market returns

[4] Baur and Lucey show that gold performs as a safe haven asset for around 15 trading days after the extreme negative shock in stock returns. The portfolio analysis indicates that an investor, who holds gold longer than 15 days may suffer losses from holding a position in gold too long.

on average in these markets. As for bonds, Baur and Lucey did not find any evidence for gold being a hedge or a safe haven asset against bonds.

The analysis of Baur and Lucey did not take the Global Financial Crisis into account. Extending the analysis of Baur and Lucey, Baur and McDermott (2010) used a 30-year data covering time period from 1979 to 2009 to examine the role of gold in the global financial system. The main hypothesis of their research was, whether gold represents a safe haven against developed and emerging countries equities. In addition, Baur and McDermott distinguished weak and strong form of safe haven and hedge asset. A strong hedge asset is negatively correlated with stock markets on average, whereas weak hedge asset is uncorrelated (zero correlation) with stocks on average. A strong safe haven, is defined as an asset, which is negatively correlated with equities during periods of extreme negative returns, whereas weak safe haven asset is only uncorrelated with equities during corresponding periods. The results give evidence of safe haven and hedge asset effects for most developed countries' stock markets, such as for major European stock markets and the US. For those European and US stock markets, gold is observed to be a strong safe haven. In contrast, Baur and McDermott observed that gold is neither safe haven nor a hedge asset for Australia, Canada, Japan and BRIC countries. For emerging markets gold is at best, observed to be a weak safe haven. According to Baur and McDermott, this indicates that the significance of safe haven assets in emerging market is not as evident as it is in developed markets, which might be due to investors portfolio allocation behaviour. Instead of looking at safe haven assets in emerging markets when suffering heavy losses, investors might prefer to draw their funds from emerging market equities and reallocate them into developed market equities. The results also suggest that investors use gold as safe haven when global economic uncertainty rises, but in extreme cases of global uncertainty gold market moves in the same direction as do the global stock markets limiting the safe haven role of gold under global uncertainty. Interestingly, the results also indicate that the safe haven role of gold is currency dependent. According to analysis of Baur and McDermott, the common currency denomination of gold and stock indices induces generally higher comovement even in extreme market conditions, which in turn reduces the usability of gold as safe haven asset during periods of uncertainty.

Previous research has also studied, whether financial speculation could explain the safe haven property of gold. Baur and Glover (2012) theorized that significant investments in gold can undermine the safe haven property of gold. The results of their research indicate that speculative trading may affect the safe haven properties of gold in the long horizon, whereas in the short run safe haven properties still exist. Baur and Glover propose that the more investors hold gold in their portfolios against the stock market shocks, the more the safe haven properties of gold are likely to suffer in periods of financial turmoil, because of different contagion mechanisms between these markets.

Uncertainty in the financial markets is usually related to high volatility of asset returns. Empirical research has shown that in the stock markets, volatility is inversely related to stock returns, which implies that volatility is expected to be higher during periods of declining stock prices. Evidence of the asymmetric volatility in equity markets is, for example, provided by Bekaert and Wu (2000). Based on this evidence, Hood and Malik (2013) studied the safe haven effects of gold under changing stock market volatility. Using the data from 1995 to 2009, Hood and Malik show that gold represents hedge and weak safe haven properties against the U.S stocks. However, the findings of Hood and Malik show that in periods of extremely low and high volatility, gold does not display negative correlation with US stocks. This evidence suggests that the safe haven role of gold is not evident during periods of extreme uncertainty, such as during the global financial crisis in 2008. On the contrary, Hood and Malik show that VIX index has negative correlation with stock markets even during the periods of extremely high volatility, which suggests that VIX index related investment products, such as VIX futures, could be a superior hedging tool against stock markets compared to gold.

Empirical research has also examined the relationship between oil and gold prices. Researchers have proposed that the theoretical motivation for the co-movement between gold and oil prices comes from the relationship between inflation and gold prices. As discussed earlier, investors have traditionally used gold to hedge against inflation. The increase in oil price induces the increase in general price level, which implies higher inflation. As inflation increases, the demand for gold increases, which pushes gold prices up. Thus, the inflation channel suggests that there is a positive relationship between oil and gold prices. Based on this theoretical motivation, Narayan, Narayan and Zhen (2010) studied the long-run relationship between gold and crude oil futures prices at different levels of maturity using cointegration analysis. The results suggest that gold and oil spot and futures markets cointegrated up to the maturity of 10 months. According to Narayan et. al. the results indicate that investors have used gold as a hedge against inflation (or oil price movements) and oil prices can predict gold market prices. Similarly, Zhang and Wei (2010) showed using daily data from 2000 to 2008 that crude oil and gold prices cointegrated, which supports the earlier evidence that crude oil and gold prices share a similar long-run price trend. However, the evidence of their Granger causality test indicates that there is a linear Granger causality from crude oil to gold prices but not vice versa. This evidence supports the theoretical hypothesis, that an increase in oil price causes an increase in gold price.

Following the research on the relationship between gold and oil prices, Reboredo (2013) examined, whether gold provides a hedge or safe haven against oil price movements. Using copula analysis and data from January 2000 to September 2011, Reboredo finds evidence of an average positive dependence gold and oil markets. This evidence implies that gold cannot be used as a hedge asset against oil price fluctuations. However, the copula analysis reveals that there is tail independence between oil and gold prices, which indicates that gold provides safe haven against negative oil market shocks.

The safe haven property of gold against equities and oil implies that there is a negative correlation between gold and equities and oil especially in periods of market stress. As stated in the previous chapter, the financialization of commodity markets has induced not only an increase in correlations across equities, but also an increase in correlations between commodities and equities. However, for example the empirical evidence of Creti et. al. (2013) reveals that the correlation between gold and S&P 500 index decreased significantly during the global financial crisis in 2008, whereas other commodities became more correlated with the index during the crisis. This evidence gives a further support, from correlation perspective, that gold provides a safe haven against stock market crashes.

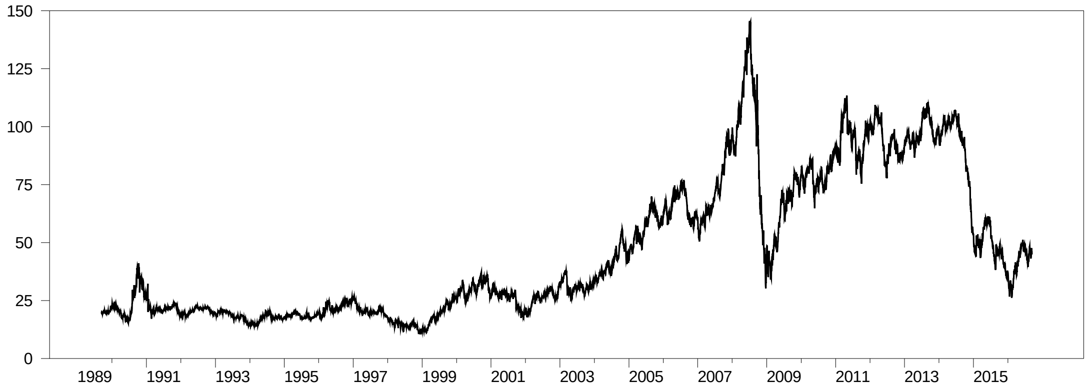
4.2 Crude oil markets

Crude oil is one of the most important commodities traded in the global markets and it plays a significant role in macroeconomic variables, such as inflation, exchange rates and economic growth. The most used benchmarks for crude oil prices are WTI Cushing Crude Oil Spot Price, traded in New York Mercantile Exchange (NYMEX) and North Sea Brent, traded in Intercontinental Exchange (ICE). As in case of other commodities, the fundamental price of crude oil is based on the equilibrium of demand and supply. According to Behmiri and Manso (2013), crude oil prices react to economic, political, meteorological, financial and technological factors. In addition, Behmiri and Manso note that information about oil reserves has an impact on crude oil prices. A special feature of crude oil is that crude oil is an exhaustible resource. According to Hamilton (2008), scarcity and speculation of oil have become relevant pricing factors for crude oil.

Crude oil is the most demanded fossil fuel in the world, contributing a 38 percent share of the total fossil consumption in 2010. In 2011, the largest share of the total world crude oil consumption came from OECD countries (51,1 %) and USA, Japan and China were the three largest world crude oil consumers. As for the supply side, OPEC member countries account for the largest share of crude oil supply, having 72,5 percent share of the world. (Behmiri & Manso, 2013)

Figure 3 below presents WTI crude oil prices, in dollars, from September 1989 to September 2016. Crude oil price movement shows a continuous increase from 1999 to 2008. It is also worth noting that the oil price movements show some steep increases, which are followed by abrupt drops. For example, in July 2008 before the outbreak of global financial crisis, the price of WTI crude oil peaked at 145,31 dollars per barrel and by the late December 2008 the crude oil price dropped 79 percent to 30,28 dollars per barrel. Another significant drop was experienced between 2014 and 2016, when the excess oil supply and decreasing global demand pressed down oil prices by 75 percent. All in all, Figure 3 reveals that crude oil price fluctuates over a wide range, showing rapid increases and decreases over the sample period.

Figure 3 Crude Oil-WTI spot price (Source: Datastream)



A theoretical motivation for the co-movements between crude oil and stock market prices can be found from the asset pricing theory. Traditional asset pricing theory suggests that asset prices are determined based on expected cash-flows. Thus, an increase in oil price should induce higher costs for companies, which use oil as an input in production. Higher costs, in turn, decrease expected cash-flows, which should lead to a decrease in stock prices. On the other hand, for oil exporting economies higher oil prices imply higher revenues, which should be accompanied by an increase in the stock prices. From another perspective, an increase in oil price should have positive impacts on the whole economy of oil exporting countries because of increased income in oil exporting country. An increase in income should, in turn, enhance country's economic conditions, which should be reflected positively in the stock markets. Jimenez-Rodriguez and Sanchez (2005) provide evidence from OECD countries that oil-importing countries suffer from rising oil prices. Thus, rising oil prices should be reflected negatively in the stock markets of oil importing economies.

Empirical research has studied extensively the relationship between crude oil and stock market prices and it has provided supporting evidence on the theoretical relationship between crude oil and stock market prices. Jones and Kaul (1996) were among first to investigate, how stock markets react to oil price shocks. Using a standard cash-flow dividend valuation model the impacts of oil price shocks on stock market returns, they provided evidence of the negative relationship between crude oil price changes and aggregate stock market returns. The results also indicate that for U.S and Canadian stock markets, the stock market reactions on the changes in oil price can be explained by the impact of oil price changes on cash flows, which is consistent with the theoretical link between crude oil and stock market prices. However, in case of Japan and United Kingdom the impact of oil price changes on stock prices cannot be only justified by changes in cash flows or by changes in expected returns. In these countries, the reaction is larger than changes in cash flows would predict.

In addition, numerous other research papers have confirmed this negative relationship. For example, Park and Ratti (2008) used a multivariate VAR analysis to investigate the impacts of oil price shocks on real stock returns over the period from January 1986 to December. Using the sample of real stock returns in the U.S and 13 European countries, Park and Ratti showed that oil price shocks have a statistically significant impact on real stock market returns. The results indicated that oil price shocks had a negative effect on stock market returns for U.S and 12 European countries. However, the causality was positive for Norwegian stock markets, which is justifiable, since Norway is an oil-exporting country. This result gives further support for the asymmetric impacts of oil price shocks. Miller and Ratti (2009) used cointegrated vector autoregressive model to study long-run relationship between the crude oil prices and international stock markets over the period from January 1971 and March 2008. The results of cointegration analysis suggest negative long-run relationship between the world price of crude oil and stock market returns for six OECD countries. Kilian and Park (2009), in turn, show that unanticipated changes in crude oil prices, driven by demand and supply shocks, explain about 20 % of the long-run changes in U.S returns.

Recent empirical literature has also suggested that the influence of oil price shocks on stock market returns is asymmetric. Sim and Zhou (2015) provided an alternative method to model the dependence between oil prices and U.S stock returns. They proposed a quantile-on-quantile regression model to investigate the impact of extreme shocks in oil price on stock market returns. The method also enables identification of reaction of stock market prices on oil price shocks in different stock market conditions. The results indicate that negative oil price shocks have a positive impact on stock market returns especially when the U.S stock market is performing well. However, the results also indicate that positive oil price shocks have weak influence on U.S stock market returns. Similarly, Lee and Chiou (2011) found asymmetric effects of oil price shocks on U.S stock market returns. The findings of Lee and Chiou suggest that the influence of oil price shocks on stock returns depends on the dynamics of oil price and oil price volatility. Lee and Chiou show that asymmetric effects only exist in high oil price volatility environment. The findings of Lee and Chiou also verify the negative relationship between oil prices and stock market returns in the U.S.

As already mentioned above, empirical literature has also provided evidence of the positive relationship between crude oil and stock market returns. The positive impacts are usually reported in case of oil-exporting economies. For example, Arouri and Rault (2012) studied the links between oil prices and stock markets in countries belonging to Gulf Cooperation Council (GCC)[5] using bootstrap panel cointegration and SUR methods. The results of cointegration analysis suggest that there is a long-run relationship between oil prices and stock markets. Moreover, the results of SUR analysis indicate a positive impact of higher oil prices on stock market returns, except in Saudi Arabia, which is theoretically justifiable, because GCC countries are major oil exporters in global oil markets and hence benefit from high oil prices.

To sum up, the empirical evidence suggests that the impacts of crude oil price shocks on stock market returns vary across countries depending, whether

[5] GCC countries include Bahrain, Oman, Kuwait, Qatar, Saudi Arabia and the United Arab Emirates.

a country is a net exporter or net importer of oil. For oil-importing countries empirical findings predict negative correlation between crude oil and equity returns, whereas for oil-exporting countries the correlation should be negative. The empirical literature on time-varying correlations between crude oil and equities has mostly focused on the U.S markets. When investigating previous literature on dynamic co-movements between conditional crude oil equities, the evidence shows that before the global financial crisis the correlations have remained low, fluctuating around zero, showing both positive and negative values. (see, e.g. Choi & Hammoudeh, 2010; Creti et. al., 2013).

Previous empirical literature has also examined, how financial distress affects the correlation between crude oil and equities. Based on the earlier evidence on the relationship between crude oil and equities Filis et. al. (2011) studied, using a DCC-GARCH-GJR approach, the time-varying correlation between oil and stock market prices to identify, how correlations vary in periods of economic uncertainty. In order to take the asymmetric effects of oil price shocks into consideration, they analysed the correlations separately for oil-exporting and oil-importing economies. The sample consisted of monthly data from 1987 to 2009 of three oil-exporting countries (Canada, Mexico and Brazil) and three oil-importing countries (USA, Germany and Netherlands). Interestingly the results of Filis et. al. show that correlations between stock and oil prices do not show different patterns for oil-exporting and oil-importing countries. However, Filis et. al. find that oil price shocks, originated from precautionary demand shocks[6] and aggregate demand side shocks[7], seem to have a significant effect on the relationship between oil and stock prices. The effects are observed to be similar for oil-exporting and oil-importing countries. The results also suggest that aggregate demand-side oil price shocks have caused a positive correlation between oil prices and stock market prices, whereas precautionary demand shocks cause the correlations to be negative. As for supply shocks, such OPEC production cuts and hurricanes, do not seem to have a significant effect on the correlation between oil and stock markets. To sum up, because aggregate demand shocks induce a positive correlation between crude oil and equity returns, one may conclude that oil does not provide a safe haven against losses in stock markets in periods of economic turbulence.

Previous empirical research also reports that Global financial crisis has imposed a structural break in the time-varying correlation between crude oil and U.S equity returns. The evidence suggests that cross-market linkages between crude oil and U.S equity returns increased significantly as a result of global financial turmoil, which is reflected in a higher correlation between crude oil and stock market returns than before the crisis period. Numerous empirical researches have reported a significant jump from negative to positive in the correlation between crude oil prices and U.S stock market prices during the global financial crisis in 2008 (see. e.g Filis et. al., 2011, Kolodziej et. al., 2014; Creti et. al.,

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[6] For example, terrorist attacks and wars.

[7] Such as, Asian crisis, Housing Market Boom, Chinese economic growth and global financial crisis in 2008,

2013). As already discussed in the previous chapter, similar structural breaks are also found in other commodities, for example, in case of agricultural products and commodity indexes (see e.g. Creti et. al., 2013; Büyüksahin & Robe, 2014).

As discussed in the previous chapter, cross-market contagion and financialization of commodity markets, as stated by Tang and Xiong (2012), might explain the significant increase in the correlation between oil and stock prices. On the other hand, Büyüksahin and Robe (2014) suggested that the higher correlation is related to the higher investment activity of hedge funds in commodity markets. The empirical evidence shows that the correlations have also persisted higher after the global financial crisis in 2008. Kolodziej et. al. (2014) provide an alternative theoretical explanation for the radical change in the correlation relying on the Capital Asset Pricing model. Using the Capital Asset Pricing model, Kolodziej et. al. formulated the expected return for crude oil as follows:

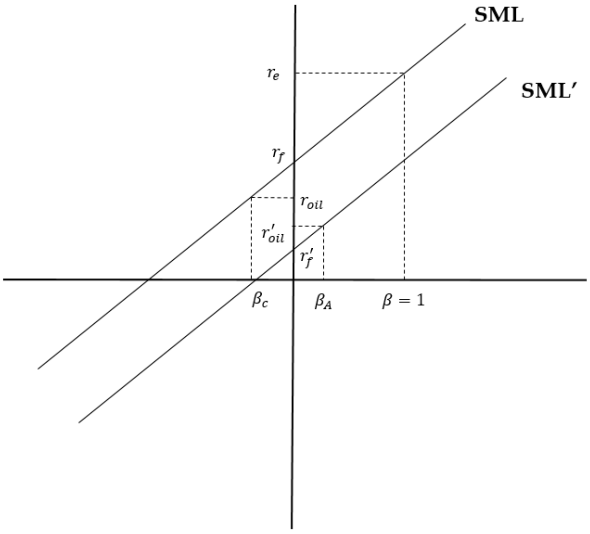
$$E(r_{oil,t}) = r_{f,t} + \beta[E(r_{e,t}) - r_{f,t}], \tag{16}$$

where $r_{f,t}$ is risk-free rate at time t, $E(r_{e,t})$ denotes an expected return for equities at time t. The correlation between crude oil and stock market prices can be related to beta coefficient as follows:

$$\beta = \frac{\rho\sigma_{oil}^2}{\sigma_{equities}^2}, \tag{17}$$

where ρ denotes the correlation between commodities and equities. Equation (17) implies that the beta coefficient and the correlation coefficient carry the same sign because variances for crude oil and equity returns cannot receive negative values, implying that they are always positive. Figure 4 explains the flip in the correlation from negative to positive during the Global financial crisis in 2008. Before the outbreak of global financial crisis, crude oil showed negative correlation with S&P500 stock market index, which implies negative beta coefficient in the CAPM framework. Because risk-free rate receives small values, the expected return for crude oil as a financial asset should carry small or even negative returns. As interest rates dropped dramatically during the fourth quarter in 2008, CAPM forecasts a drop in the expected return for crude oil as well. In Figure 4 below, the significant reduction in the interest rate shifts the security market line (SML) downwards. In the CAPM framework, the reduction in the interest rate would press the returns for crude oil downward. Thus, CAPM is not useful by itself to explain the change in the correlation.

Figure 4 The change in correlation between crude oil and equities in CAPM framework (Kolodziej et. al., 2014)



In order to understand the dramatic change in the correlation from negative to positive, convenience yields for crude oil futures have to be taken into account. When convenience yields are high, there is an incentive to hold physical commodity, whereas in case of low convenience yields commodities are preferred to hold as financial asset. [8]According to Kolodziej et. al., the reduction in the interest rate level resulted in lower convenience yields for crude oil futures, which increased the incentive to hold crude oil as financial asset. Following the formulation of Pindryck (2001), Kolodziej. et. al determine the convenience yield as follows:

$$C_t = (1 + r_f)S_t - F_{tT} - k_t \tag{18}$$

where C_t denotes capitalized flow of marginal convenience yield at time t, S is the spot price, F is the price for the futures contract and k denotes the cost of physical storage per unit. Equation (18) shows that a decrease in interest rate level lowers the marginal convenience yields. Pindryck (2001) proposed that when convenience yields are high, the commodity futures market is likely to be in backwardation, because the demand for physical crude oil is higher than for the futures contracts. On the other hand, when convenience yields are low, the commodity futures market is likely to be in contango, in which futures contract prices for maturities onwards are higher than the current spot price. Using the theorem of Pindryck, Kolodziej et. al. hypothesized that the reduction in the convenience yields pushed the crude oil futures market into contango. In contango market investors expect to benefit from holding crude oil as financial asset, because the capital gains are expected to dominate convenience yields in contango market

[8] High convenience yield implies that holding a physical commodity generates more return than holding a commodity as financial asset.

(Pindryck, 2001). As expected returns for crude oil futures increase in contango market, the beta coefficient flips from negative to positive in CAPM framework. Relying on the Equation (17), positive beta coefficient implies that the correlation between crude oil and equities is positive.

It is worth noting that Kolodziej et. al did not provide any empirical testing to support this theoretical hypothesis for the change in correlation. However, this theoretical framework is useful for understanding investor behaviour in commodity futures market. As interest rate level decreased significantly in 2008, lower convenience yields increased the incentive to hold crude oil as financial asset, which increased the correlation between crude oil and stock market prices. However, in recent empirical research papers, the samples do not cover a long period after global financial crisis. Because interest rate level has stayed close to zero, it would be interesting to study how interest rates have evolved after 2008.

Alongside Kolodziej et. al. other researchers have also provided the drastic reduction in the interest rate level as an explanation for the increased correlation between crude oil futures and equity returns. For example, recently Datta et. al. (2017) provided theoretical and empirical evidence that the correlation between crude oil and equity returns increases in zero interest rate environment. Using a new-Keynesian model, augmented with oil and zero-lower bound on nominal interest rates, they showed that the dynamics of oil and equity prices changes significantly, when the nominal interest rate is at its zero lower bound. The model shows that as central banks are constrained to conduct their monetary policies at zero lower bound, central banks are not able to respond to changes in inflation, whereas in high interest rate environment central banks normally do respond to these changes. Hence, the real interest rate responds differently to changes in zero interest rate environment than when interest rates are higher. For this reason, shocks have different impacts on crude oil and equity prices on zero lower bound than away from it. The model implies that a decline in crude oil supply increases the price of oil, which accelerates inflation. As nominal interest rates do not respond to changes in inflation at zero lower bound, the real interest rate decreases, which reduces households' desire to save by investing in interest yielding assets. Consequently, households increase their demand for non-oil production, which causes the rental rate of capital and hence, equity prices to increase. As a result of this mechanism, crude oil and equity prices move in the same direction at the zero lower bound on nominal interest rate. However, when interest rates are higher, the model suggests that oil and equity prices move in opposite direction. Datta et. al. also provided empirical evidence, which supports the hypothesis that crude oil and equity returns become more correlated in zero interest rate environment.

5 EMPIRICAL ANALYSIS

Empirical analysis focuses on the examination of dynamic conditional correlations between commodity futures and equity prices by providing evidence from gold and crude oil in the U.S market. This analysis focuses especially on the identification of the impacts of financial crisis on these correlations. In addition, by extending the time horizon from 1989 to 2016, it is possible to study, how these correlations have evolved in zero-interest rate environment. Unlike previous studies, this study also includes, for comparison, a correlation analysis between commodity futures and energy sector equities. Finally, I will examine how crude oil and gold futures can be used as hedging instruments against stock market investments, especially in periods of financial turmoil.

5.1 Data

The dataset consists of daily observations for CMX Gold Futures continuous settlement prices and West Texas Intermediate (WTI) crude oil futures near month settlement prices, which are denominated as U.S dollars per barrel. As for equity market prices, the analysis relies on S&P 500 Composite Total Return Index, which is one of the most relevant stock market indexes in the US. Regarding the energy sector, S&P 500 Energy IG Price Index is used to measure the stock market development. The index comprises the companies included in S&P 500 index, which are classified as the GICS energy sector. is collected from Thomson Reuters Datastream and it covers a period from September 11, 1989 to September 13, 2016. The prices are also denominated in U.S dollars.

Figures below illustrate the time series observations on the sample used in the analysis. For preliminary co-movement analysis, the time series on crude oil and gold futures price observations are plotted together with S&P 500 Index and S&P 500 Energy IG Price index observations. Figure 5a illustrates the development of S&P 500 Total Return index and Crude oil-WTI futures near month settlement price. From Figure 5a we can see that crude oil futures prices and S&P 500 index movements were unrelated on average from 1989 to the early 2000s. During the IT bubble in the beginning of 2000s, we can see that S&P 500 and crude oil futures showed similar price trends. Before the onset of global financial crisis, we can see that the settlement price of crude oil futures skyrocketed. The onset of global financial crisis, initiated by the bankruptcy of Lehman Brothers in September 2008, triggered a significant drop in the crude oil futures and equity prices, as figure 5a illustrates. In addition, especially starting from the Global financial crisis, thr crude oil futures and the U.S equity prices showed similar price trends until 2013, when the settlement prices of crude oil futures dropped, reflecting the excess global supply of crude oil.

Figure 5a Time series on S&P 500 Total Return Index and Crude oil -WTI futures near month settlement price from September 11, 1989 to September 13, 2016

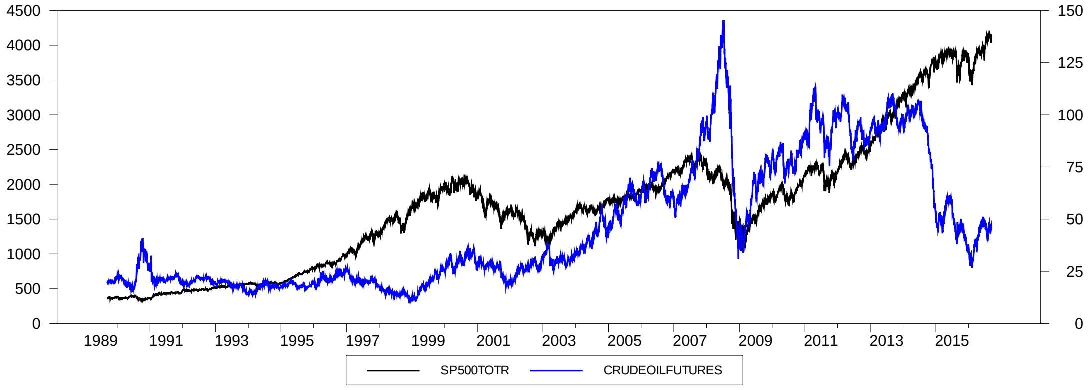
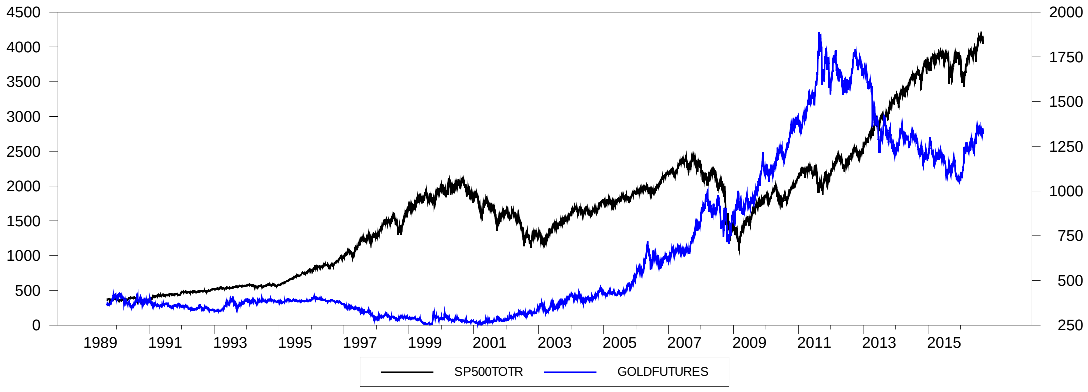


Figure 5b below plots the evolution of CMX gold futures continuous settlement price and S&P 500 Total Return index. Unlike in case of crude oil, gold futures and equity prices show unrelated or even adverse price trends throughout the sample period. As for financial crises, during the IT bubble gold futures showed positive price development, whereas the equity prices dropped. Similarly, during the outbreak of global financial crisis, gold futures showed adverse price movement compared to equity prices, which is consistent with previous empirical evidence that gold provides a safe haven against U.S equity price changes.

Figure 5b Time series on S&P 500 Total Return Index and CMX Gold futures continuous settlement price from September 11, 1989 to September 13, 2016.



Figures 5c and 5d below plot the time series of crude oil and gold futures together with S&P 500 Energy IG Price index. Figure 5c shows a clear co-movement between crude oil and energy sector stocks. The similar price movements are justifiable, because the revenues of energy sector firms are dependent on the price level of crude oil. A careful review of the plot reveals that co-movement between these time series intensified starting from 2003, when index investors emerged in commodity markets. As for gold futures, a preliminary analysis using Figure 5d reveals that starting from 2003 gold futures and energy sector stocks started show similar price trends, which also reflects the financialization of commodity markets. However, more careful co-movement analysis will be presented later in this chapter.

Figure 5c Time series on S&P 500 Energy IG Price index and Crude oil-WTI futures near month settlement price from September 11, 1989 to September 13, 2016.

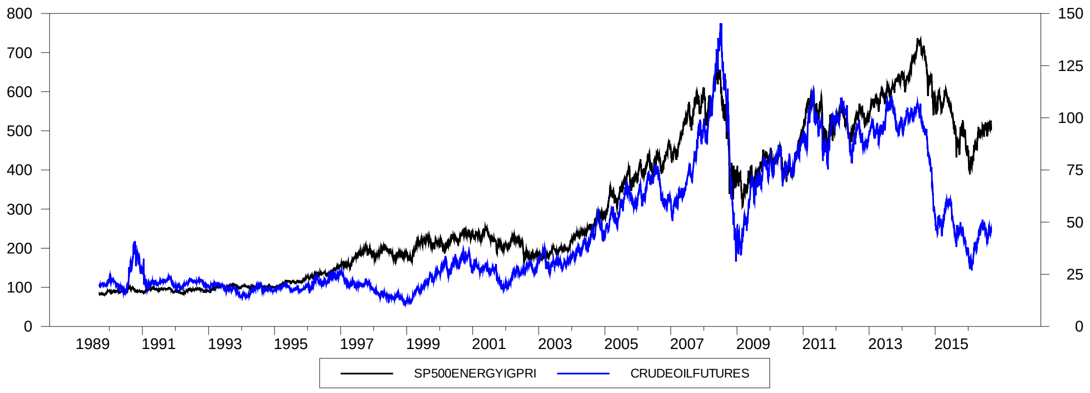
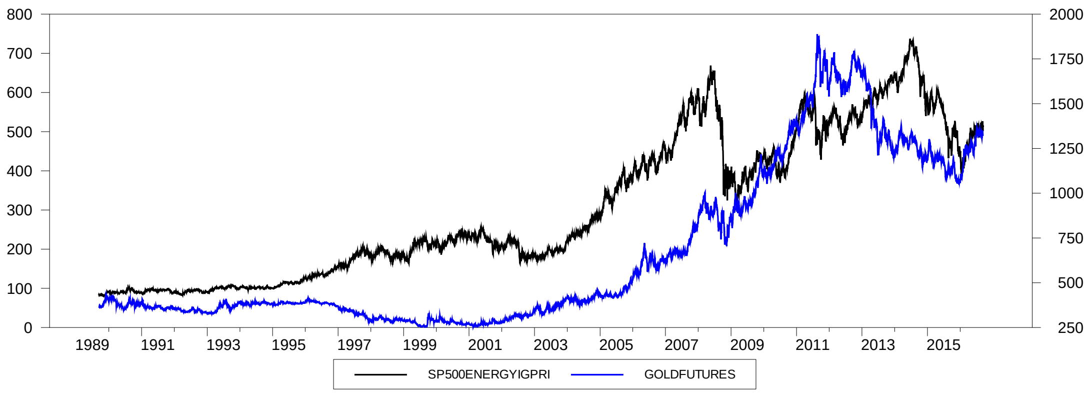


Figure 5d Time series on S&P 500 Energy IG Price index and CMX gold futures continuous settlement price from September 11, 1989 to September 13, 2016.



Before building the model for correlation analysis, the unit root tests are conducted to check the stationarity of the asset price series. The unit root tests are conducted using Augmented Dickey Fuller and Phillips Perron test, which take autocorrelated residuals into consideration. Moreover, the stationary test of Kwiatkowski, Phillips, Schmidt and Shin (1992) is used to test the robustness of unit root test results. Table 1 provides unit root test results to the order of integration of all price variables. The results show that all variables are I(1) processes, which means that all price level series are non-stationary. The unit root test results imply that series must be differenced once to ensure stationarity of variables. As a result of the unit root test results, the remainder of this empirical analysis discusses the co-movements between commodity futures and equity prices by using daily logarithmic return series, defined as follows:

$$r_t = 100\times[\ln(P_t) - \ln(P_{t-1})], \quad (19)$$

where $\ln(P_t)$ denotes logarithmic transformation of price in period t and $\ln(P_{t-1})$ logarithmic transformation in previous period t-1.

Table 1 Unit root test results

	ADF	Phillips-Perron	KPSS
Crude-oil WTI	I(1)	I(1)	I(1)
CMX Gold	I(1)	I(1)	I(1)
S&P 500 Total Return Index	I(1)	I(1)	I(1)
S&P 500 Energy IG Price Ind	I(1)	I(1)	I(1)

Notes: I(d) indicates the order of integration of time series. The series, which is d order integrated, contains d unit roots. The degree of integration is decided based on 5 % statistical significance level.

Table 2 reports descriptive statistics for all the return series. The sample consists of 7046 observations for each return variable. From September 11, 1989 to September 13, 2017 the mean daily total rate of return on Crude-oil WTI futures was 0.01 %, with a minimum daily return of -41.55 % and a maximum of 22.92 %. An abnormally low daily drop in the Crude-oil WTI futures price was due to oil price shock in 1990, which occurred in response to Iraqi invasion of Kuwait. We can see that the daily average return on gold futures is slightly higher than of crude oil. Interestingly, the standard deviation of gold futures is also significantly lower than the standard deviation of WTI crude oil futures indicating higher risk-adjusted return for gold futures. As for equities, the average daily returns of S&P 500 and S&P 500 Energy IG Price indexes were higher than in case of crude oil and gold futures. The standard deviations for stock market indexes indicate lower volatility for stocks than for WTI crude oil futures, but higher volatility than for gold futures returns. Expectedly, S&P 500 Energy sector index has higher volatility than S&P 500 Total Return Index.

Time series on daily returns are reported in Appendix 1. Plots reveal an interesting feature of commodity futures returns. Firstly, crude oil futures show more intensive extreme returns than aggregate U.S equities and energy sector equities. As for gold futures, the extreme daily returns are lower than in case of equities and crude oil, but gold futures show more frequent extreme returns than equities and crude oil futures. One reason for this might the centralized trading in gold markets. As discussed in the previous chapter, central banks are one of the key investors in gold market, which implies that their actions may induce extreme returns in gold. For example, in 1999 HM Treasury announced to sell approximately half of the U.K gold reserves, which resulted in extended bear market in gold price. As a result of these actions the price of physical gold decreased to its lowest levels in 20 years. In addition, the safe haven role and speculative demand for gold futures may induce frequent extreme returns.

The shape of the probability distributions of daily returns are described using excess kurtosis and skewness statistics. Excess kurtosis is defined as a difference between kurtosis statistic and value 3, where value 3 represents kurtosis under normal distribution. Kurtosis statistics indicate that each variable shows statistically significant positive excess kurtosis, which implies that their probability distributions have fat tails. Moreover, negative skewness figures indicate that probability distributions are negatively skewed in each case. From probability perspective, this implies all these assets have higher probability of extremely negative returns than extremely positive returns. Jarque-Bera test is used to test, how well skewness and kurtosis jointly match normal distribution. Jarque-Bera test statistics show that the null hypothesis of normally distributed asset returns is rejected in every case at 1 % significance level.

Modelling, which this empirical analysis relies on, represents a family of non-linear models. Thus, it is reasonable to test, whether these non-linear models are appropriate for the data used in analysis. Testing for non-linear ARCH effects is carried out with the test proposed by Engle (1982). Test statistics indicate that the null hypothesis is rejected for each variable, suggesting the presence of non-linear ARCH effects in crude oil, gold, S&P 500 TOTR and S&P 500 Energy sector index returns. Thus, using non-linear models in the analysis is now justified.

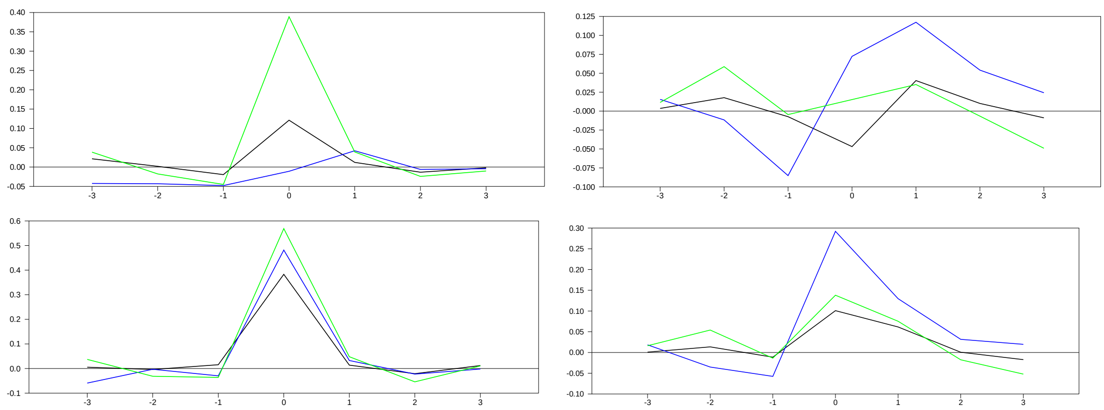
Table 2 Descriptive statistics

	Crude-oil WTI	CMX Gold	S&P 500 Total Return Index	S&P 500 Energy IG Price Index
Observations	7046	7046	7046	7046
Mean	0.01 %	0.02 %	0.03 %	0.03 %
Standard deviation	2.37	1.02	1.11	1.47
Minimum	-41.55 %	-9.82 %	-9.46 %	-16.88 %
Maximum	22.92 %	8.87 %	10.96 %	16.96 %
Kurtosis (excess)	18.27 ***	8.19 ***	9.07 ***	11.30 ***
Skewness	-0.71 ***	-0.24 ***	-0.27 ***	-0.28 ***
Jarque Bera	98553.56 ***	19737.39 ***	24257.94 ***	37551.03 ***
ARCH test	239.76 ***	261.82 ***	1384.44 ***	1780.07 ***

Notes: The statistical significance of a statistic is indicated with stars. * indicates statistical significance at 10 % level, ** indicates 5 % significance level and *** indicates 1 % significance level respectively.

As a preliminary tool for choosing a correlation model for the empirical analysis, figures below plot cross correlations between commodity and equity returns, used in the analysis. Using different subsamples, the figures clearly indicate variation in cross-correlations between different sample periods. Thus, variation in cross-correlations give further support that co-movements should be modelled with time-varying correlation models.

Figure 6a/b/c/d Cross correlations



Notes: In Figure 6a (upper left), 6b (upper right), 6c (lower left) and 6d (lower right) black line shows cross-correlation calculated using sample from September 11,1989 to September 13, 2016, blue line using sample from January, 2004 to September 2008 and green line using from October, 2008 to September 2016.

5.2 Methodology

Time-varying conditional correlations are estimated with Generalized Diagonal DCC GARCH model of Capiello et. al. (2006). In case of DCC GARCH Estimation is carried out in three step process. In the first step vector autoregressive model is estimated for variables, from which residuals are obtained for the dynamic conditional correlation model. VAR model is constructed as follows:

$$\begin{pmatrix} y_{1t} \\ y_{2t} \\ y_{3t} \end{pmatrix} = \begin{pmatrix} \beta_{10} \\ \beta_{20} \\ \beta_{30} \end{pmatrix} + \begin{pmatrix} \pi_{1,1} & \pi_{1,2} & \pi_{1,3} \\ \pi_{2,1} & \pi_{2,2} & \pi_{2,3} \\ \pi_{3,1} & \pi_{3,2} & \pi_{3,3} \end{pmatrix} \begin{pmatrix} y_{1t-1} \\ y_{2t-1} \\ y_{3t-1} \end{pmatrix} + \begin{pmatrix} e_{1t} \\ e_{2t} \\ e_{3t} \end{pmatrix}, \tag{20}$$

where y_{1t} denotes WTI crude oil futures logarithmic return time-series, y_{2t} CMX gold futures return time-series and y_{3t} S&P 500 index return series. Following the version of Capiello et. al., using the 3x1 vector of residuals obtained from VAR model above, the 3x3 conditional covariance matrix H_t is decomposed as follows:

$$H_t = D_t P_t D_t \, , \tag{21}$$

where D_t is 3x3 diagonal matrix of conditional standard deviations and P_t time-varying correlation matrix. In order to capture leverage effects[9] and volatility clustering in conditional variances, conditional standard deviations are estimated by using univariate GJR (1,1) GARCH model proposed by Glosten, Jagannathan and Runkle (1993).

$$h_{i,t}^2 = \alpha_{0,i} + \alpha_{1,i} u_{i,t-1}^2 + \beta_i h_{i,t-1} + \gamma_i u_{i,t-1}^2 I_{i,t-1} \, , \tag{22}$$

where $I_{i,t-1} = \begin{cases} 1 \text{ } if \text{ } u_{i,t-1} < 0 \\ 0 \text{ } otherwise \end{cases}$ and $i = 1,2,3.$

The constant coefficient $\alpha_{0,i}$ is the estimate for constant volatility, whereas $\alpha_{1,i}$ measures the impact of lagged return shocks of asset i on its conditional variance and β_i gives the influence of the conditional variance in previous period on the conditional variance in current period. Possible asymmetries in conditional variance are given by coefficient γ_i.

Once conditional standard deviations are estimated from univariate processes, the residuals, obtained from VAR model estimated in the first step, are standardized with conditional standard deviations. Formally, the standardized residuals are defined as follows:

$$\varepsilon_{i,t} = e_{i,t} / \sqrt{h_{i,t}^2} \tag{23}$$

[9] Leverage effect implies asymmetric effects of innovations on conditional variances.

Using the 3x1 vector of standardized residuals, the evolution of conditional correlation is given by the following equation. Now the conditional correlation matrix P_t can be defined as follows:

$$P_t = diag\{Q_t\}^{-1} Q_t diag\{Q_t\}^{-1}, \tag{24}$$

in which $diag\{Q_t\}^{-1}$ is an inverted 3x3 matrix containing, the square root of diagonal elements of Q_t, where Q_t denotes a 3x3 time-varying conditional correlation matrix for the returns. Using generalized diagonal DCC model, proposed by Capiello et. al. (2006), the evolution of conditional correlation matrix is given by the following equation[10]:

$$Q_t = \bar{P}(ii' - aa' - bb') + aa' \circ \varepsilon_{t-1}\varepsilon_{t-1} + bb' \circ Q_{t-1} \tag{25}$$

The coefficients are estimated by maximizing the likelihood function described in Equation (7) in Chapter 2. Once the model is estimated, the time-varying conditional correlation series are given by:

$$\rho_{i,j,t} = \frac{q_{i,j,t}}{\sqrt{q_{ii,t} q_{jj,t}}} \tag{26}$$

Once dynamic conditional correlations are calculated, I will calculate risk-minimizing dynamic hedge ratios to examine, whether gold and crude oil futures can be used to hedge spot positions in S&P 500 Total Return Index and S&P 500 Energy IG Price index. The risk minimizing dynamic hedge ratios are calculated following the specification of Kroner and Sultan (1993), which is given by the following equation:

$$\beta_t = \frac{h_{sf,t}}{h_{ff,t}}, \tag{27}$$

where $h_{ij,t}$ denotes time-varying conditional covariance between spot and futures returns and $h_{ff,t}$ is time-varying conditional variance of the returns of futures contracts, both measured at time t. The time-varying variances and convariances are obtained from time-varying variance-covariance matrix, which is estimated with Generalized Diagonal DCC-GARCH model. Let's consider an investor, who has a \$1 long position in stock markets. In order to minimize the risk of this \$1 long position in equities, the investor should short \$ β of crude oil or gold futures in this case. In case of a negative hedge ratio, investor should hold a long position in futures contracts.

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[10] Correlation equation selection was conducted between Generalized Diagonal DCC GARCH model and Asymmetric Generalized Diagonal DCC GARCH model, both proposed by Capiello et. al (2006). Stability conditions indicated that AGD-DCC model does not fit to data, whereas Generalized Diagonal DCC model fulfilled stability conditions.

5.3 Empirical results and discussion

Empirical results will be reported and discussed in this section. This section is organized as follows. First, the regression parameters of the models will be reported and discussed. Then, I will report and discuss the time-varying correlations, which are followed by the dynamic hedge ratios and discussion on how crude oil and gold futures can be used as a hedging instruments against equity investments.

5.3.1 Parameter estimates

Tables 3a and 3b report parameter estimates of VAR model, univariate GJR-GARCH model and Generalized Diagonal DCC GARCH correlation equation. Table 3a provides parameter estimates for the model using crude oil futures, gold futures and S&P 500 Total Return Index returns as the variables. The parameter estimates of VAR model for crude oil futures returns show that only lagged crude oil futures returns Granger cause crude oil futures returns in period t at 5 % significance level. The negative sign of lagged returns suggests a mean reverting behaviour of the returns. As for gold futures returns, parameter estimates show that lagged crude oil futures returns Granger cause present gold futures returns at 10 % significance level. Positive sign is consistent with the evidence of Reboredo (2013), who found a positive dependence between crude oil and gold prices. However, statistically significant positive parameter estimate of lagged S&P500 returns is inconsistent with earlier evidence of the safe haven role of gold futures.[11] One explanation for positive parameter estimate is that it may imply positive dependence between gold futures and U.S equities in the long-run. As previous research indicated, gold provides a safe haven against extreme negative returns in U.S equities. Moreover, as already discussed in Chapter 4, the results of Baur and Lucey (2010) indicate that safe haven effect functions only for a short period of time and effect is observed for extreme returns. The last column reports parameter estimates of VAR model for S&P500 returns. Negative parameter estimate of lagged S&P500 return series indicates a mean reverting behaviour of S&P 500 index returns. Interestingly, lagged crude oil returns do not have statistically significant impact on S&P 500 total returns. As discussed in the previous chapter, empirical research has reported a negative relationship between crude oil and stock markets in the U.S. Thus, the sign of the coefficient estimate does not support earlier empirical evidence of the relationship between crude oil prices and stock market returns.

The parameter estimates of conditional variance equation for crude oil and gold futures show that lagged shocks in returns and lagged conditional variance have statistically significant effect on conditional variance in current period.

[11] Theoretically the safe haven role of gold would imply that lagged S&P 500 TOTR index returns Granger cause gold futures returns with negative sign.

However, lagged return shocks do not have statistically significant effect on conditional variances of S&P500 index in this sample. As for the response to return shocks, consistent with earlier evidence (see e.g Bekaert & Wu, 2000), the conditional variances of S&P500 returns show leverage effect implying higher volatility in response to negative returns than positive return shocks. The volatility of crude oil futures returns does not show asymmetric reactions to negative and positive shocks. Interestingly, the parameter estimate for gold futures returns indicates that positive return shocks increase volatility more than negative return shocks which opposite to the leverage effect in volatility reported in equity markets. According to Baur (2012) this asymmetric volatility is due to safe haven role of gold. Baur hypothesizes that the increase in the price of gold can be interpreted as an increase of safe-haven purchases from investors. In turn, these safe-haven purchases can be interpreted as a signal of higher uncertainty and risk in financial markets and macroeconomic conditions, which leads to higher volatility in the gold markets. On the other hand, negative returns in the gold markets can be interpreted to lower volatility of gold futures returns respectively. Stationarity conditions[12] of conditional variance equations hold for each variable, which implies that conditional variances are stationary processes. However, in case of gold, the univariate process is an integrated process (stationarity condition equals one), which means that shocks in gold futures returns have permanent effect on future volatilities. As for correlation equation parameter estimates, the coefficients are statistically significant at 1 % significance level, which indicates that Generalized Diagonal DCC GARCH can be used to describe dynamic co-movements in this dataset.

Table 3b reports the coefficients for the model, which incorporates S&P500 Energy sector index. The coefficients of VAR (1)-system indicate that crude oil futures returns and S&P 500 Energy sector index returns show bi-directional causality, which is justifiable as the energy sector index includes oil companies, which benefit from higher oil prices. In addition, S&P 500 Energy sector index shows mean reverting behaviour. Like in case of S&P 500 TOTR index, the lagged returns of S&P 500 Energy sector index have positive impact on gold futures returns at 1 % significance level, which is again against the evidence of the safe haven role of gold in the financial markets. The univariate conditional variance equation reveals, that like S&P500 TOTR index, the energy sector index also shows leverage effect in its conditional variance. The parameter estimates of Generalized Diagonal DCC correlation equation are statistically significant at 1 % significance level, which implies that the correlation model fits to the dataset well.

[12] Stationarity condition: $\alpha_1 + \beta + \frac{1}{2}\gamma \leq 1$

Table 3a Parameter estimates for correlation model of commodity futures and S&P500 TOTR

VAR(1) Equation			
	Crude oil -WTI	*CMX Gold*	*S&P 500 TOTR*
Constant	0.01116	0.01728	0.03606 ***
Crude oil $_{t-1}$	-0.02493 **	0.00985 *	-0.00525
Gold $_{t-1}$	-0.01351	-0.00913	-0.00855
S&P 500 $_{t-1}$	0.03160	0.03414 ***	-0.05668 ***
The Univariate GJR-GARCH(1,1) Equation			
	Crude oil -WTI	*CMX Gold*	*S&P 500 TOTR*
α_0	0.03161 ***	0.00233 **	0.01559 ***
α_1	0.06525 ***	0.05452 ***	-0.00181
β	0.92612 ***	0.96091 ***	0.92125 ***
γ	0.01210	-0.03086 ***	0.12590 ***
Stationarity condition:	0.99743	1.0000	0.98240
Generalized Diagonal DCC Correlation Equation			
a	0.15969 ***	0.11001 ***	0.12685 ***
b	0.98538 ***	0.98918 ***	0.99040 ***

Table 3b Parameter estimates for correlation model of commodity futures and S&P500 Energy index.

VAR(1) Equation			
	Crude oil -WTI	*CMX Gold*	*S&P 500 Energy*
Constant	0.01128	0.01752	0.02742
Crude oil $_{t-1}$	-0.03322 **	0.00207	0.02998 ***
Gold $_{t-1}$	-0.01779	-0.01355	-0.01809
S&P 500 Energy $_{t-1}$	0.04393 **	0.04243 ***	-0.07935 ***
The Univariate GJR-GARCH(1,1) Equation			
	Crude oil -WTI	*CMX Gold*	*S&P 500 Energy*
α_0	0.03168 ***	0.00233 **	0.01494 ***
α_1	0.06536 ***	0.05430 ***	0.02807 ***
β	0.92611 ***	0.96104 ***	0.93912 ***
γ	0.01187	-0.03086 ***	0.04874 ***
Stationarity condition:	0.99743	1.0000	0.99156
Generalized Diagonal DCC Correlation Equation			
a	0.12291 ***	0.11627 ***	0.10966 ***
b	0.99160 ***	0.98738 ***	0.99383 ***

5.3.2 Dynamic conditional correlations

Figure 7a plots the dynamic conditional correlation between crude oil futures and S&P 500 Total Return index returns. Consistent with earlier evidence, before the global financial crisis the correlation shows mean reverting behaviour around zero. Moreover, it is worth noticing that the correlation is highly volatile. The sample used in this analysis incorporates two major financial crises: IT bubble in 2001 and the Global financial crisis in 2008. During the IT bubble the correlation between crude oil futures and U.S equities did not increase significantly. However, as previous research has also reported, the correlation jumped significantly after the collapse of Lehman Brothers in 2008. As Figure 7a shows the Global financial crisis imposed a structural break in the correlation. After the global financial crisis, the correlation between crude oil futures and U.S equities returns has stayed at higher level until the end of sample period, which is against the theoretical relationship between crude oil prices and stock market returns. This result has already been confirmed by previous research papers (see. e.g Filis et. al., 2011, Kolodziej et. al., 2014; Creti et. al., 2013) However, the Figure 7a reveals that correlation dropped significantly in 2013, but started to increase again in late 2014.

The longer time-series used in this analysis reveals that the correlation has stayed exceptionally high after the global financial crisis. As discussed in the previous chapter, the zero-interest rate environment might partly explain the higher correlation between crude oil futures and U.S equity returns. One possible explanation for higher correlation might be the low convenience yields because of zero interest rate environment. Low convenience yields make trading in futures contracts more attractive than trading the physical crude oil. On the other hand, low interest rate environment also makes interest yielding less attractive because of their low yield. I hypothesize that the low interest rate environment and low convenience yields have increased the investment activity in crude oil futures markets as they have become more attractive part of investment portfolios of especially the institutional investors.

When analysing the shape of futures price curve [13]in WTI crude oil futures, the crude oil futures market has normally been in backwardation until 2005. Since 2005, contango market has become a normal condition in the crude oil futures market. As discussed in previous chapter, the crude oil market switched from backwardation to contango after the outbreak of Global financial crisis, which was associated with increase in the correlation between crude oil futures and U.S equity returns. Kolodziej et. al. (2004) proposed that in contango market crude oil is more beneficial to trade as financial asset, since capital gains dominate convenience yields, especially in low interest rate environment. However, the crude oil futures forward curve inverted from contango to backwardation in late 2012. As Figure 7a shows, this was associated with a decline in the correlation between crude oil futures and S&P 500 total returns in 2014. Since late 2014, the crude oil futures market switched again from backwardation to contango market due to global oversupply in crude oil. Previous literature has shown that there is a negative relationship between convenience yields and crude oil inventories. For example, Alquist et. al. (2014) confirmed that convenience yields and U.S crude oil inventories are negatively related. Hence, I hypothesize that convenience yields decreased in 2014 because of global oversupply in crude oil, which again pushed the futures market to contango. Figure 7a shows that in 2014 the correlation between crude oil futures and S&P 500 TOTR index started to increase again. Based on earlier discussion, it seems that in contango market, when crude oil futures are more attractive to hold as financial assets, the correlation with S&P 500 TOTR index has been higher than in periods of backwardation market.

[13] The shape of crude oil futures price curve is displayed in Appendix 3

Relying on the evidence of Büyüksahin and Robe (2014), especially traders, who trade both equities and crude oil, increase the cross-market linkage in the rates of returns in U.S equities and crude oil futures. Hence, I hypothesize that in contango market, those traders are more likely to increase their positions in crude oil. However, this hypothesis remains to be tested empirically in future research, because of the limited availability of the data on those positions.

Figure 7a Dynamic correlation between crude oil futures and S&P 500 TOTR index returns

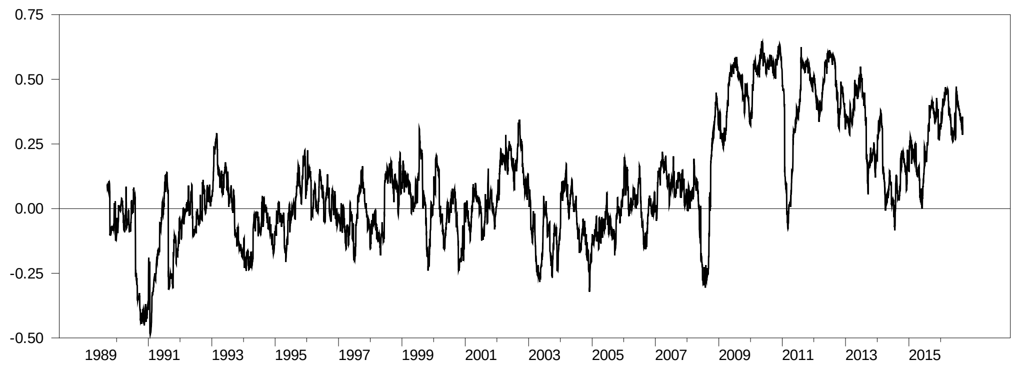


Figure 7b illustrates the time-varying correlation between gold futures and S&P 500 TOTR index returns. The time series plot shows that correlation is showing high volatility and it is fluctuating around zero value. During the IT bubble at the beginning of 2000's, the correlation declined significantly showing negative values. In addition, during global financial crisis in 2008 and European credit crisis in 2010 the correlation between gold and U.S equities has been negative, which gives further support for the hypothesis that gold futures provide a safe haven against U.S equities as earlier research has shown. However, high volatility of the correlation shows that safe haven effect is only temporary, especially during global financial crisis, which is consistent with the evidence of Baur and Lucey (2010), who also showed that gold provides a safe haven only for a short time period. Interestingly the correlation showed high volatility and high positive values in the aftermath of global financial crisis, which could indicate higher economic uncertainty in global economy. By looking at the evolution of the conditional correlation from 2014, the correlation has stayed clearly below zero, suggesting that gold may have provided a hedge against S&P 500 index in recent years.

Figure 7b Dynamic correlation between gold futures and S&P 500 TOTR index returns

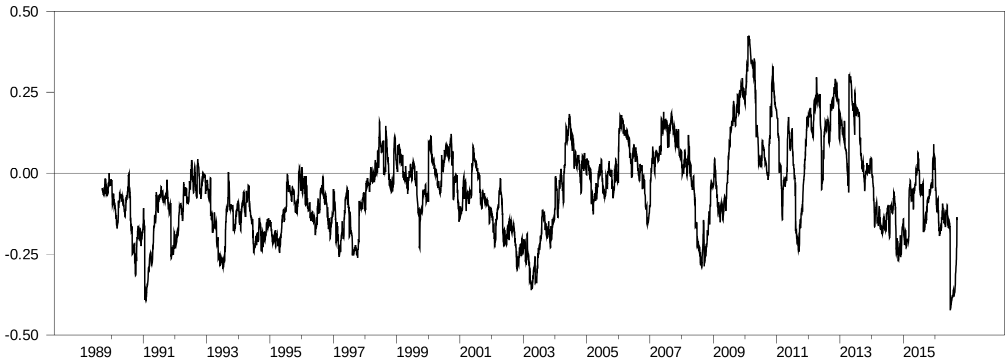


Figure 7c plots the time-varying conditional correlation time-series between crude oil futures and S&P 500 Energy IG Price index returns. Unlike in case of S&P 500 TOTR index, the correlation between crude oil futures and energy sector index returns shows fluctuation around positive value. As discussed earlier, the positive average correlation is justifiable, as the revenues of energy sector firms depend partly on the price of crude oil. However, Figure 7c also reveals that the correlation increased significantly starting from 2003 shifting the average level of correlation upwards. The shift in correlation between crude oil futures and S&P 500 Energy IG Price index returns could indicate that financialization of commodity markets intensified the cross-market linkages between crude oil futures and U.S energy sector equities. Investors can speculate crude oil price movements by investing in energy sector firms or directly in crude oil linked financial products. Hence, because of increased supply of commodity-linked investment products, it seems that crude oil and energy sector equity prices have become more related after 2004. Unlike in case of S&P 500 index, interestingly the correlation did not increase significantly during the global financial crisis as it did in case of crude oil futures and S&P 500 TOTR index.

Figure 7c Dynamic correlation between crude oil futures and S&P 500 Energy IG Price index returns

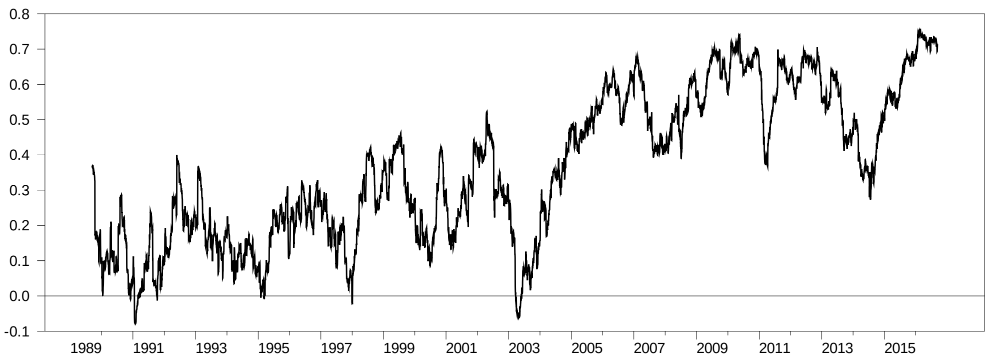
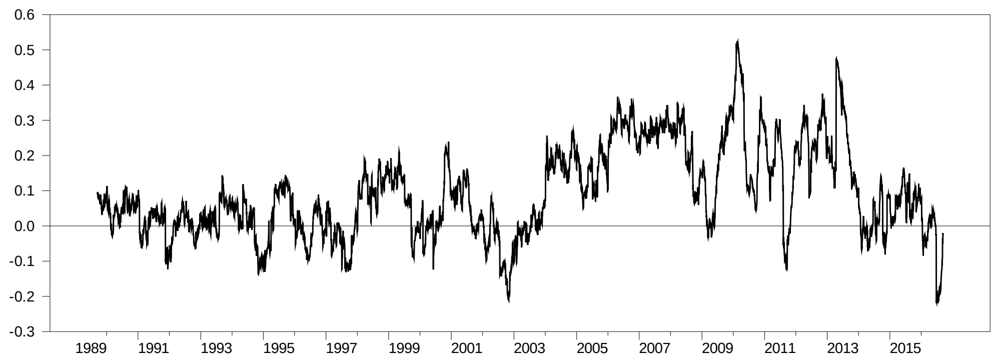


Figure 7d plots the dynamic conditional correlation between gold futures and S&P 500 Energy IG Price index returns. Previous literature has not studied the safe haven effect of gold against energy sector equities. The evolution of the correlation shows that as in case of crude oil futures, the financialization of commodity markets imposed a structural break in the correlation as well. Before 2004, the correlation between gold futures and U.S energy sector equities fluctuated around zero. After 2004, the average level of correlation increased and remained higher until the outbreak of Global financial crisis. Unlike in case of gold and S&P 500 index, the correlation does not show negative values during the stock market crash in 2008, which suggests that gold did not provide a safe haven against U.S energy sector equities during that period. Similarly, as in case of S&P 500 TOTR index and gold futures, in the aftermath of global financial crisis the correlation between gold futures and energy sector equities also shows volatile behaviour reflecting the uncertainty in global economy. However, as in case of S&P 500 TOTR index, the correlation has also in this case decreased significantly and has stayed lower in recent years.

Figure 7d Dynamic correlation between gold futures S&P 500 Energy IG Price index returns

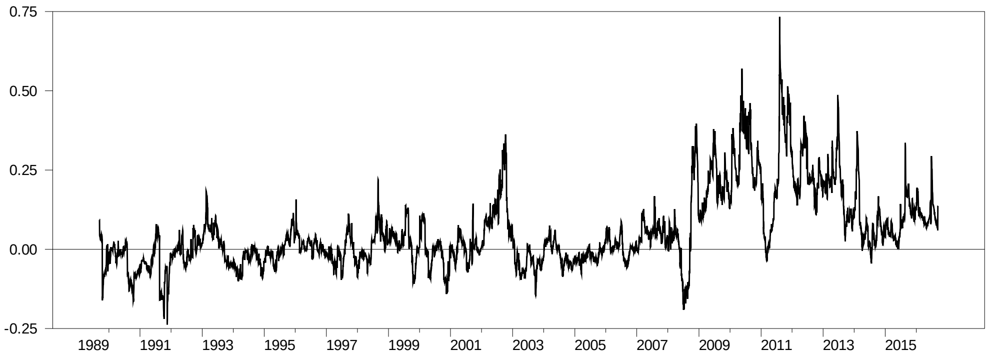


5.3.3 Dynamic hedge ratios

Figure 8a plot the risk-minimizing hedge ratio for crude oil futures against S&P 500 Total Return index. When scrutinizing the periods of stock market crises, the hedge ratio shows abrupt increases during those periods indicating. Interestingly enough, the hedge ratio peaks nearly as high in the aftermath of IT bubble as after the outbreak of Global financial crisis. The structural change in the correlation between crude oil futures and S&P 500 TOTR index returns after the Global financial crisis has also been reflected as higher hedge ratios for crude oil futures. The higher hedge ratio makes crude oil futures less attractive hedging instruments against U.S equities, because investors are required higher short positions to minimize the risk in aggregate U.S equity investments. Moreover, the hedge ratio is more volatile in than it was before the Global financial crisis. This implies that in order to maintain a risk minimizing hedge against positions in S&P 500 TOTR index, investors have to rebalance strongly their positions in crude oil futures. Considering the transaction costs, the high volatility of hedge ratio implies higher costs of hedging because the hedging position needs to be rebalanced often. Because of high volatility of hedge ratio and abrupt increases in periods of financial crises, crude oil futures

As discussed in context of correlation analysis, the correlation between crude oil futures and seems to be higher in contango market especially in recent years, whereas in high backwardation market the correlation seems to be lower. From hedging perspective, backwardation market seems to be more attractive, because of lower correlation. Figure 8a confirms this, since the hedge ratio has been significantly lower, when crude oil futures market is in backwardation especially before the outbreak of Global financial crisis and during 2014. However, the hedge ratio has started to increase and become more volatile, as the forward curve inverted to contango at the end of 2014.

Figure 8a Dynamic hedge ratio between S&P 500 TOTR index and WTI crude oil futures



(

As for gold futures, hedge ratio becomes negative in the beginning of 2000's in the aftermath IT bubble, when the U.S stock market performed poorly. In addition, during the Global financial crisis in 2008, hedge ratio becomes negative, indicating that holding a long position in gold futures minimizes the risk of long position in S&P 500 TOTR index. This evidence supports the safe-haven hypothesis of gold in periods of financial crises. However, after global financial crisis, the hedge ratio becomes quickly positive, which implies investor should short gold futures. Hence, a long position in gold futures has only a temporary risk minimizing impact against S&P 500 TOTR index. As in case of crude oil futures, the high volatility of dynamic hedge ratio and the switches from negative between negative and positive values suggest, that in normal times the risk-minimizing hedging with gold futures might be too expensive.

Figure 8b Dynamic hedge ratio between S&P 500 TOTR index and CMX gold futures

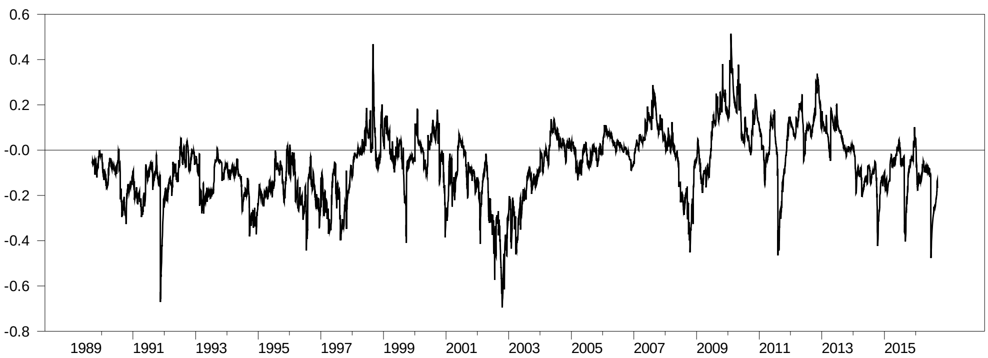


Figure 8c reveals that the shift in the correlation between crude oil futures and energy sector equities after 2004 also implies higher hedge ratio. The plot shows that there is a significant structural break in the hedge ratio, which indicates that as a result of closer integration of these markets, investors are required higher short positions in crude oil to minimize risk in energy sector equity investments. Hence, the closer integration of crude oil futures and energy sector equities has reduced the attractiveness of crude oil futures as hedging instrument against energy sector equities. In addition, as in previous cases, the high volatility of hedge ratio restricts the usability of crude oil futures as hedging instruments in normal times.

As for periods of stock market crashes, during the bear market after the IT bubble the hedge ratio did not increase significantly compared to earlier fluctuation. However, during the stock market crash in 2008, the hedge ratio peaked close to one, implying that risk-minimizing hedging against stock market crash in energy sector with crude oil futures would have required a corresponding position in crude oil futures than in energy sector equities. As Figure 5c showed earlier, crude oil decreased steeply during the outbreak of Global financial crisis, which was also reflected in declining S&P 500 Energy IG Price index, because of negative outlooks for energy sector firms. High hedge ratio during periods of financial turmoil naturally does not support using crude oil futures as risk minimizing hedging instrument against energy sector equities.

Figure 8c Dynamic hedge ratio between S&P 500 Energy IG Price index and WTI crude oil futures

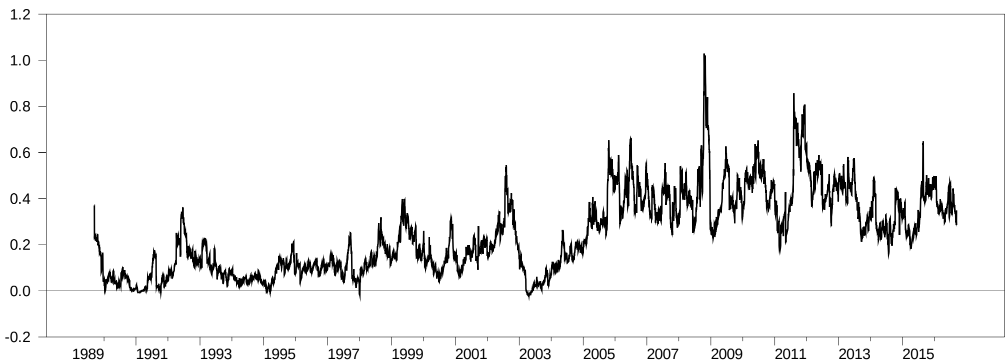
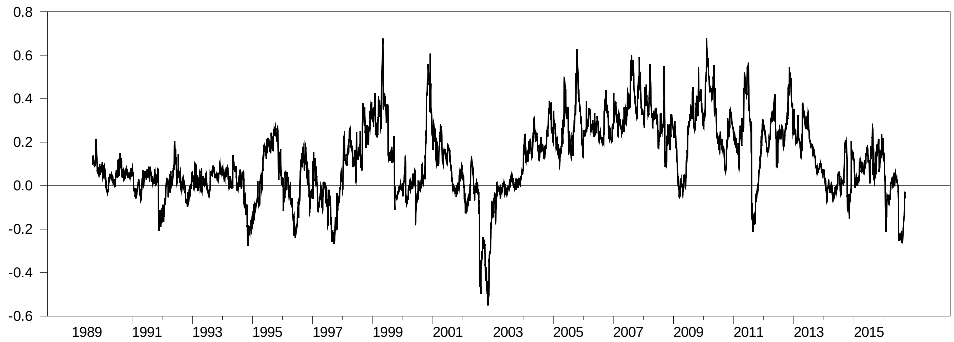


Figure 8d plots the dynamic hedge ratio for gold futures against energy sector equities. In contrast to S&P 500 TOTR index, the safe haven effects are not as evident in case of energy sector equities. During the bear market after the IT bubble the hedge ratio becomes negative, which supports the safe haven hypothesis of gold futures. However, during the stock market sell-off in 2008, the hedge ratio shows positive values. This means that investors should have shorted gold futures to minimize the risk during the stock market crash, which is against the safe haven hypothesis. Hence, this evidence finds no conclusive solution, how gold futures should be used to minimize the risk in energy sector equity investment in periods of financial distress.

As Figure 7d showed, there has been a structural break in the correlation after 2004, which lasted until 2014. During this period, the average level of hedge ratio increased, making hedging with gold futures less attractive. Speaking about the volatility of hedge ratio, as in previous cases the high volatility of hedge ratio does not favor gold futures as risk-minimizing hedging instrument in long time horizon.

Figure 8d Dynamic hedge ratio between S&P 500 Energy IG Price index and CMX gold futures



To sum up the evidence, the dynamic hedge ratios above are highly volatile, which suggests that hedging with crude oil and gold futures against aggregate U.S equities and energy sector equities might be too expensive. However, it is more important to scrutinize hedge ratios in periods of stock market sell-offs, because during these periods the hedging instruments are needed the most. Because of a significant increase in the hedge ratio during periods of stock market crash crude oil futures do not seem to be attractive risk-minimizing hedging instruments neither against aggregate, U.S equities, nor against U.S energy sector equities, in periods of financial turmoil. As for gold futures, a long position in gold futures seem to minimize a risk in aggregate U.S equities during stock market sell offs. However, similar conclusions cannot be drawn in case of energy sector equities.

6 CONCLUSIONS

In this Master's thesis, I examined, how the correlations between commodity futures and U.S aggregate and energy sector equities evolve in periods of financial distress by providing evidence from crude oil and gold. In order to investigate these links, I relied on Generalized Diagonal DCC GARCH model, proposed by Cappiello, Engle and Sheppard (2006). This methodology enables the investigation of time-varying dynamics of cross-market correlations and whether these correlations depend on the stock market condition. Moreover, I examined, whether crude oil and gold futures are attractive hedging instruments against aggregate U.S equities and energy sector equities by calculating dynamic hedge ratios.

The main findings of this thesis can be summarized as follows: the correlation between crude oil futures and aggregate U.S equities increases in periods of financial distress. However, since the outbreak recent Glogal financial crisis the correlation between crude oil and U.S equity returns has been higher than it was before the crisis. In addition, the results suggest that the correlation may, at least partly, depend on the shape of crude oil futures forward curve. Based on the research paper of Kolodziej et. al. (2014), I hypothesize that crude oil is more attractive to trade as financial asset when the market is in contango. Especially in low interest rate environment convenience yields for crude oil futures tend to be lower, which pushes the futures market to contango, making capital gains of crude oil futures to dominate convenience yields. Thus, during these periods the cross-market linkages increase, because traders, who also trade equities, increase their positions in crude oil futures and thus intensify the cross-market linkage between crude oil futures and aggregate U.S equities. However, this hypothesis remains to be tested in the future research. Speaking about the co-movements between crude oil futures and energy sector equity returns, the average level of correlation increased significantly after 2004. One possible explanation is that as a result of financialization of commodity markets the cross-market linkage between crude oil and energy sector equities has become stronger. As for gold futures, the evidence supports the safe haven hypothesis in periods of financial turmoil in case of aggregate U.S equities. becomes negative during major stock market crashes in the sample period. However, the safe haven effects are not as evident in case of energy sector equities.

From cross-market hedging perspective, near month crude oil futures do not seem to attractive hedging instruments against in periods of major stock market sell-offs, because investors are required significantly higher short positions during these periods. I also propose that hedging with crude oil futures might be more attractive in backwardation market, because correlation with S&P 500 index has been lower during those periods. When it comes to hedging against energy sector equities, investors are required higher short positions over the sample period compared to aggregate U.S equities. Moreover, during stock market crises the hedge ratio is significantly higher than in normal times. As time-varying correlations, also the risk-minimizing dynamic hedge ratio is highly volatile in both cases. This makes crude oil futures an expensive hedging instrument against aggregate U.S equities and energy sector equities in normal times, because the hedging position would require frequent adjustments. As gold futures, the dynamic hedge ratio indicates that investors are required to hold a long position to hedge against the risk in aggregate U.S equities in periods of stock market sell-offs. As in context of correlation analysis, this is consistent with safe haven hypothesis of gold. Thus, because of negative correlation in periods of financial turmoil, gold futures provide better hedge against aggregate U.S equities than crude oil futures. However, when it comes U.S energy sector equities, similar safe haven effects are not as evident during stock market crashes.

Future research could more closely examine cross-market hedging with commodity futures in periods of stock-market sell-offs. In addition, it would be interesting to scrutinize, whether the commodity futures forward curve and convenience yields could explain the commodity-equity correlations.

REFERENCES

Alquist,R., Bauer, G.H. & Diez de los Rios, A. 2014. What Does the Convenience Yield Curve Tell Us about the Crude Oil Market? Bank of Canada Working Paper No. 2014-42.

Arouri, M. E. H & Rault, C. 2012. Oil Prices and Stock Markets in GCC Countries: Empirical Evidence from Panel Analysis. International Journal of Finance & Economics, 17(3), 242-253.

Bashiri Behmiri, N. & Pires Manso, J.R. 2013. Crude Oil Price Movements and Determinant Factors: A Historical Overview. Available at SSRN: https://ssrn.com/abstract=2271404.

Barberis, N. & Shleifer, A. 2003. Style Investing. Journal of Financial Economics 68 (2), 161-199.

Baur, D. G. 2012. Asymmetric Volatility in the Gold Market. The Journal of Alternative Investments 14 (4), 26-38.

Baur, D.G & Glover, K.J. 2012. The Destruction of a Safe Haven Asset? Applied Finance Letters 1(1), 8-15.

Baur, D. G. & Glover, K. J. 2015. Speculative Trading in the Gold Market. International Review of Financial Analysis 39, 63-71.

Baur, D. G. & Lucey, B. M. 2010. Is Gold a Hedge or a Safe Haven? An Analysis of Stocks, Bonds and Gold. Financial Review 45 (2), 217-229.

Baur, D. G. & McDermott, T. K. 2010. Is Gold a Safe Haven? International evidence. Journal of Banking & Finance 34 (8), 1886-1898.

Bekaert, G & Wu, G. 2000. Asymmetric Volatility and Risk in Equity Markets. The Review of Financial Studies 13 (1), 1-42.

Bollerslev, T. 1986. Generalized Autoregressive Conditional Heteroskedasticity. Journal of Econometrics 31(4), 307-327.

Bollerslev, T. 1990. Modelling the Coherence in Short-Run Nominal Exchange Rates: A Multivariate Generalized Arch Model. The Review of Economics and Statistics 72 (3), 498-505

Büyüksahin, B. & Robe, M.A. 2014. Speculators, Commodities and Cross-Market Linkages. Journal of International Money and Finance 42 (1), 38-70.

Capie, F., Mills, T. C. & Wood, G. 2005. Gold as a hedge against the dollar. Journal of International Financial Markets, Institutions and Money 15 (4), 343-352.

Cappiello, L., Engle, R. F. & Shephard, K. 2006. Asymmetric Dynamics in the Correlations of Global Equity and Bond Returns. Journal of Financial Econometrics 4 (4), 537.

CFTC. 2008. "Staff Report on Commodity Swap Dealers & Index Traders with Commission Recommendations." Commodity Futures Trading Commission (September).

Cheng, I.H. & Xiong, W.2013. The financialization of commodity markets. NBER Working Paper No. 19642.

Cheung, C. S. & Miu, P. 2010. Diversification benefits of commodity futures. Journal of International Financial Markets, Institutions and Money 20 (5), 451-474.

Choi, K & Hammoudeh, S. 2010. Volatility behavior of oil, industrial commodity and stock markets in a regime-switching environment. Energy Policy 38 (8), 4388-4399.

Creti, A., Joëts, M. & Mignon, V. 2013. On the links between stock and commodity markets' volatility. Energy Economics 37, 16-28.

Daskalaki, C. & Skiadopoulos, G. 2011. Should investors include commodities in their portfolios after all? New evidence. Journal of Banking & Finance 35 (10), 2606-2626.

Datta, D., Johanssen, B.K., Kwon, H. & Vigfusson, R.J. 2017. Oil, Equities and the Zero Lower Bound. BIS Working Papers No. 617. Available at SSRN: https://ssrn.com/abstract=2940539

Engle, R. 2002. Dynamic conditional correlation — A simple class of multivariate GARCH models. Journal of Business and Economic Statistics, 20, 339−350.

Engle, R. F. 1982. Autoregressive Conditional Heteroscedasticity with Estimates of the Variance of United Kingdom Inflation. Econometrica 50 (4), 987-1007.

Engle, R. F. & Bollerslev, T. 1986. Modelling the persistence of conditional variances. Econometric Reviews 5 (1), 1-50.

Erb, C. B. 2006. The Strategic and Tactical Value of Commodity Futures. Financial Analysts Journal 62 (2), 69-97.

Falkowski, M. 2011. Financialization of Commodities. Contemporary Economics 5 (4), 4-17

Fama, E.F. and French, K.R., 1987. Commodity futures prices: Some evidence on forecast power, premiums, and the theory of storage. Journal of Business, 55-73.

Filis, G., Degiannakis, S. & 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 20 (3), 152-164.

Ghosh, D., Lewin E. J., Macmillan, P. & Wright, R. E. 2004. Gold as an inflation hedge? Studies in Economics and Finance 22 (1), 1.

Glosten, L. R., Jagannathan, R. & Runkle, D. E. 1993. On the Relation between the Expected Value and the Volatility of the Nominal Excess Return on Stocks. The Journal of Finance 48 (5), 1779-1801.

Gorton, G. & Rouwenhorst, K. G. 2006. Facts and Fantasies about Commodity Futures. Financial Analysts Journal 62 (2), 47-68.

Hamilton, J.D., 2008. Understanding crude oil prices (No. w14492). National Bureau of Economic Research.

Hood, M. & Malik, F. 2013. Is gold the best hedge and a safe haven under changing stock market volatility? Review of Financial Economics, 22 (2), 47-52.

Jimenez-Rodriguez, R., & Sanchez, M. (2005). Oil price shocks and real GDP growth: empirical evidence for some OECD countries. Applied Economics, 37(2), 201−228.

Jones, C.M. & Kaul, G. 1996. Oil and the Stock Markets. The Journal of Finance 51(2), 463-491.

Junttila, J-P & Raatikainen, J. 2017. Haven on Earth. Dynamic Connections between Gold and Stock Markets in Turbulent Times. Available at SSRN: https://ssrn.com/abstract=2916073.

Kilian, L. & Park, C. 2009. The Impact of Oil Price Shocks on the U.S Stock Market. International Economic Review 50 (4), 1267–1287.

Kolodziej, M., Kaufmann, R. K., Kulatilaka, N., Bicchetti, D. & Maystre, N. 2014. Crude oil: Commodity or financial asset? Energy Economics 46, 216-223.

Kyle, A. S. & Xiong, W. 2001. Contagion as a Wealth Effect. The Journal of Finance 56 (4), 1401-1440.

Kroner, K.F. & Sultan, J. 1993. Time-Varying Distributions and Dynamic Hedging with Foreign Currency Futures. Journal of Financial and Quantitative Analysis 28 (4), 535-551.

Lee, Y. & Chiou, J. 2011. Oil sensitivity and its asymmetric impact on the stock market. Energy 36 (1), 168-174.

Masters, Michael. 2008. Tesfimony before the Committeeon Homeland Security and Governmental Affairs, U.S. Senate (20 May). Retrieved from: http://www.hsgac.senate.gov//imo/media/doc/052008Masters.pdf?attempt=2. 5.12.2016

Mensi, W., Beljid, M., Boubaker, A. & Managi, S. 2013. Correlations and volatility spillovers across commodity and stock markets: Linking energies, food, and gold. Economic Modelling 32, 15-22.

Miller, J.I. & Ratti, R.A. 2009. Crude Oil and Stock Markets: Stability, Instability and Bubbles. Energy Economics 21 (4), 559–568.

Narayan, P. K., Narayan, S. & Zheng, X. 2010. Gold and oil futures markets: Are markets efficient? Applied Energy 87 (10), 3299-3303.

Park, J. & Ratti, R. A. 2008. Oil price shocks and stock markets in the U.S. and 13 European countries. Energy Economics 30 (5), 2587-2608.

Pindyck, R.S., 2001. The dynamics of commodity spot and futures markets: a primer. Energy Journal 22 (3), 1–29.

Reboredo, J. C. 2013. Is gold a hedge or safe haven against oil price movements? Resources Policy 38 (2), 130-137.

Silvennoinen, A. 2009. Modeling Multivariate Autoregressive Conditional Heteroskedasticity with the Double Smooth Transition Conditional Correlation GARCH Model. Journal of Financial Econometrics 7 (4), 373.

Silvennoinen, A. & Thorp, S. 2013. Financialization, crisis and commodity correlation dynamics. Journal of International Financial Markets, Institutions and Money 24, 42-65.

Sim, N. & Zhou, H. 2015. Oil prices, US stock return, and the dependence between their quantiles. Journal of Banking & Finance 55, 1-8

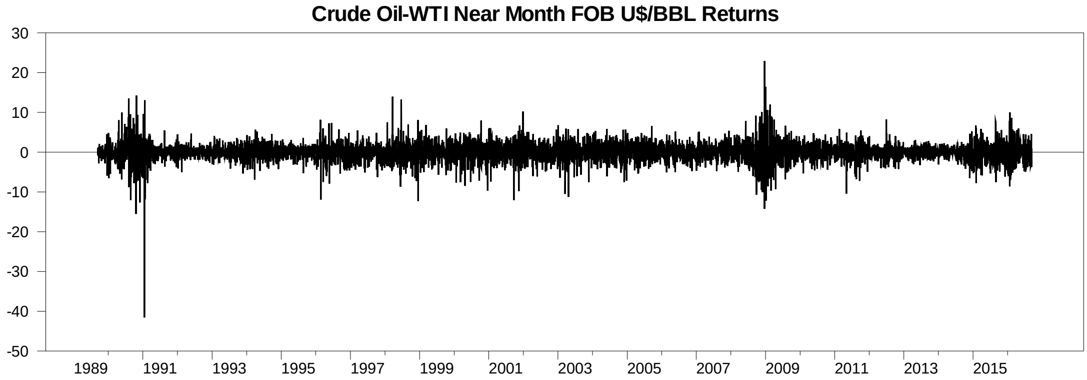
Tang, K & Xiong, W. 2012. Index investment and the financialization of commodities. Financial Analysts Journal 68 (6), 54.

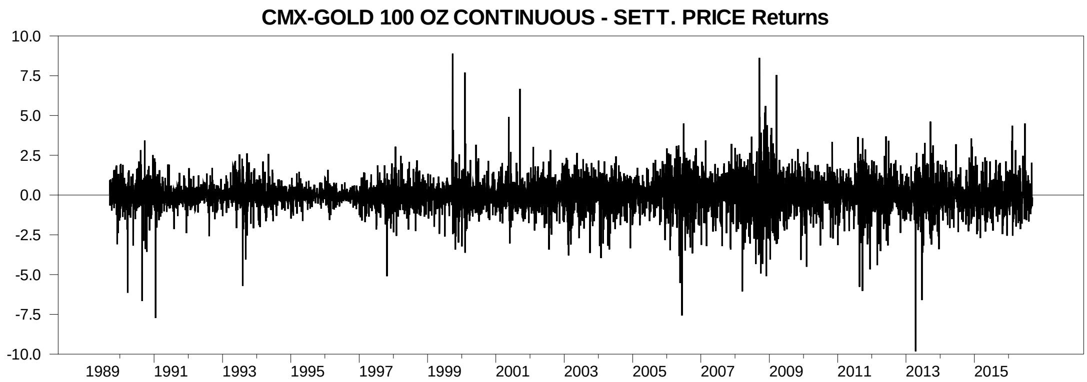
Trostle, R., (2008). Global Agricultural Supply and Demand: Factors Contributing to the Recent Increase in Food Prices, Economic Research Service Report from United States Department of Agriculture.

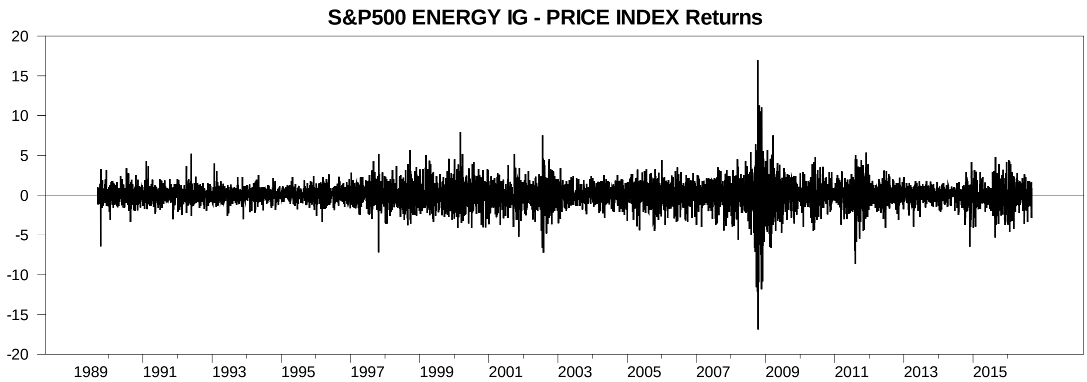
World Gold Council: http://www.gold.org/. 15.11.2016

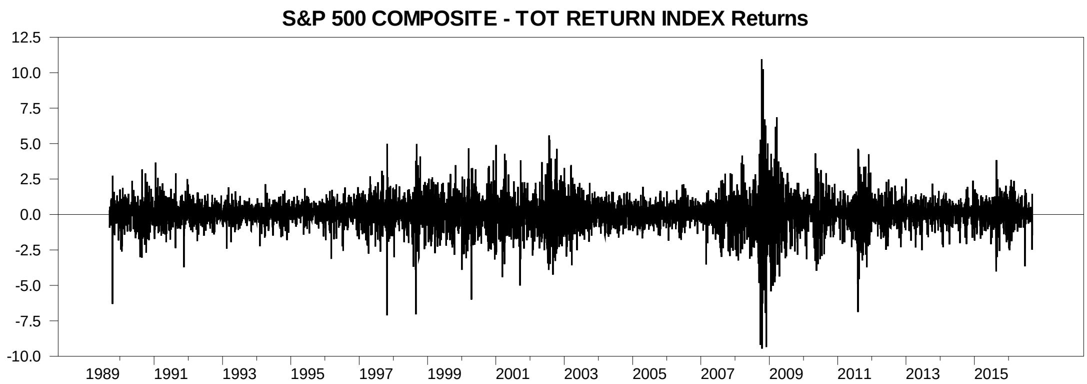
Zhang, Y. & Wei, Y. 2010. The crude oil market and the gold market: Evidence for cointegration, causality and price discovery. Resources Policy 35 (3), 168-177.

APPENDIX 1: DAILY RETURNS









APPENDIX 2: UNIT ROOT TEST STATISTICS

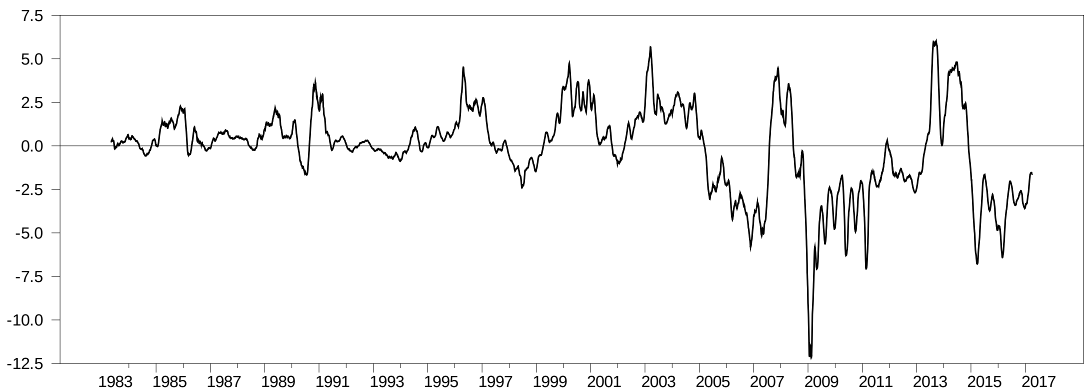
Unit root test statistics for price series

	ADF	Phillips-Perron	KPSS
Crude-oil WTI	-1,6829	-1,63655	99.50095 ***
CMX Gold	-0,3959	-0,36826	106.4362 ***
S&P 500 Total Return Index	0,4248	0,46166	112.2780 ***
S&P 500 Energy IG Price Index	-1,1814	-1,21966	126.8662 ***

Unit root test statistics for return series

	ADF	Phillips-Perron	KPSS
Crude-oil WTI	-85.9737 ***	-86.0588 ***	0,077244
CMX Gold	-84.4667 ***	-84.4887 ***	0,261158
S&P 500 Total Return Index	-88.8988 ***	-89.1088 ***	0,121128
S&P 500 Energy IG Price Index	-65.1773 ***	-89.6203 ***	0.069243

APPENDIX 3: THE SHAPE OF FUTURES PRICE CURVE IN WTI CRUDE OIL FUTURES



Notes: The shape of futures price curve in WTI crude oil futures is defined as 30 day moving average of the continuous settlement price difference (USD/bbl) between near month contract and 6th listed contract on the price curve in WTI crude oil futures. Positive values indicate that WTI crude oil futures market in normal backwardation, whereas negative values imply that the futures market is in contango. (Source: Datastream)