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Dynamic correlation between stock market and oil prices: The case of oil-importing and oil-exporting countries

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ABSTRACT

The paper investigates the time-varying correlation between stock market prices and oil prices for oil-importing and oil-exporting countries. A DCC-GARCH approach is employed to test the above hypothesis based on data from six countries; Oil-exporting: Canada, Mexico, Brazil and Oil-importing: USA, Germany, Netherlands. The contemporaneous correlation results show that i) although time-varying correlation does not differ for oil-importing and oil-exporting economies, ii) the correlation increases positively (negatively) in response to important aggregate demand-side (precautionary demand) oil price shocks, which are caused due to global business cycle's fluctuations or world turmoil (i.e. wars). Supply-side oil price shocks do not influence the relationship of the two markets. The lagged correlation results show that oil prices exercise a negative effect in all stock markets, regardless the origin of the oil price shock. The only exception is the 2008 global financial crisis where the lagged oil prices exhibit a positive correlation with stock markets.

Keywords: oil prices, stock market returns, DCC-GARCH, dynamic correlation.

JEL: C32, C51, G15, Q43

1. Introduction

This paper investigates the contemporaneous and lagged time-varying correlation between stock market prices and oil prices for oil-importing and oil-exporting countries considering the origin of oil price shocks. In particular, we consider Kilian's (2009) and Hamilton's (2009) origins of oil price shocks (aggregate demand-side shock, precautionary demand shock and supply-side shock)¹. The main events, occurred during the period of study, are tied up with the origins of oil price shocks. Despite the fact that oil price effects on macroeconomic variables have been extensively studied², the literature on the relationship between stock market and oil prices is still growing. Nevertheless, there are very few studies on the dynamic correlation between these two markets. A first approach on the dynamic co-movements between oil prices and stock markets was performed by Ewing and Thomson (2007), using the cyclical components of oil prices and stock prices. They concluded that crude oil prices are pro-cyclical and lag stock prices by 6 months. Bharn and Nikolova (2010) have also examined the dynamic correlation between stock market and oil prices, in Russia, using a bivariate EGARCH model. They identified three major events (i.e. September 11th, 2001 terrorist attack, war in Iraq 2003 and the civil war in Iraq in 2006) which caused a negative correlation between the Russian stock market and the oil prices.

In the present study a robust quantitative technique is employed, namely Dynamic Conditional Correlation GARCH, or DCC-GARCH, that has not been applied before to investigate the time-varying correlation between oil and stock market prices³, considering the origin of the oil price shock. In addition, this paper belongs to a limited number of studies which make a distinction on the relationship between oil prices and stock market between oil-importing and oil-exporting countries, (see for example Apergis and Miller, 2009 and Park and Ratti, 2008). More specifically, Park and Ratti (2008) having examined 13 European countries, they concluded that positive oil price shocks cause positive returns for the Norwegian stock market (oil-exporter), whereas the opposite happens to the rest of the 13 European stock markets (oil-importers). Apergis and Miller (2009), on the other hand,

¹ According to Kilian (2009), aggregate demand-side shocks occur due to global business cycle's fluctuations, precautionary demand shocks occur due to the uncertainty of future oil supply based on the expectations of future oil demand, and supply-side shocks are exogenous shocks and occur due to reduction of crude oil availability.

² See for example, Hamilton, 1983; Burbridge and Harrison, 1984; Gisser and Goodwin, 1986; Hamilton, 1988a, 1998b; Mork et al., 1994; Lee et al., 1995; Ferderer, 1996; Hondroyannis and Papapetrou, 2001; Papapetrou, 2001; Jones et al., 2004; Huntington, 2007; Kilian, 2008a; Jimenez-Rodriguez, 2009; Berument et al., 2010.

³ Similar models to DCC-GARCH have been used to test the time-varying correlation between i) the volatility of oil spot prices and forward returns (see for example Manera et al., 2006), ii) macroeconomic prices such as GDP, inflation and output gap (see for example Lee, 2006) and iii) stock and bond returns (see for example Andersson et al., 2008).

concluded that stock markets (both from oil-importing and oil-exporting countries) tend not to react to oil price shocks (either positive or negative).

In this paper, Engle's (2002) DCC-GARCH framework is employed using data, from 1987 to 2009, for six countries; three oil-exporting: Canada, Mexico, Brazil and three oil-importing: US, Germany, Netherlands. The DCC-GARCH can be successively estimated for large time-varying covariance matrices, while it requires the estimation of less number of parameters than other multivariate GARCH models. For technical information about the advantages of the DCC-GARCH model, the interested reader is referred to Xekalaki and Degiannakis (2010).

To the best of authors' knowledge, this is the first paper that examines the dynamic correlation between stock market and oil prices using a DCC-GARCH model and thus, this paper significantly adds to the existing and growing literature of this research area.

The rest of the paper is organised as follows: Section 2 present the oil price chronology for the period under consideration, section 3 reviews the literature, section 4 describes the model and data used, section 5 presents the empirical findings of the research and, finally, section 6 concludes the study.

2. Oil price chronology

Figure 1 presents the Brent crude oil prices, in dollars, from January 1987 to September 2009. Oil price movements show some important peaks and troughs during the period of the study. The main events that took place in the period under consideration are presented in Table 1.

[FIGURE 1 HERE]

[TABLE 1 HERE]

The main peaks which are observed from Figure 1 are in October 1990, where prices almost doubled within one year. Another peak is observed in September 2000, which was a result of a continuing increase in oil prices since 1999. From 1992 until late 2008 we observe a continuing increase in oil prices, with some disruptions (e.g. during 2007), as well. The prices reached a peak in late 2008. A final peak is observed in June 2009, where prices increased by more than 60% since the January 2009 price levels.

The main troughs are observed in the early 1999, where prices fell by almost 50% since 1997, in December 2001, where oil prices fell by 50% since September 2000, in January 2007, where prices fell by almost 40% compared to the mid-2006 prices, and in early 2009, where oil prices fell by more than 70% compared to the June 2008 peak levels.

An important observation that can be made from the above graph is the fact that most of the oil price changes occurred due to precautionary crude oil demand changes. However, there are four aggregate demand-side oil price shocks. One occurred during the Asian economic crisis, the second took place in 2000, where interest rates decreased significantly and that created a bust in the housing market and construction industries. The third took place in the period 2006-2007, which was a result from the rising demand of oil from China and the fourth demand-side oil price shock took place in the recent global financial crisis of 2008.

3. Theory and review of the literature

Economic theory suggests that any asset price should be determined by its expected discounted cash flows (Williams, 1938; Fisher, 1930). Thus, any factor that could alter the expected discounted cash flows should have a significant effect on these asset prices. Consequently, any oil price increase would result to increased costs, restraining profits and in greater extend, would cause a decrease in shareholders value. Hence, any oil price increase should be accompanied by a decrease in the stock prices. Should that effect be the same for oil-importing and oil-exporting countries, though?

Many authors argue that oil price effect on stock markets is an indirect effect and it is fed through the macroeconomic indicators. According to Bjornland (2009) and Jimenez-Rodriguez and Sanchez (2005), an oil price increase is expected to have a positive effect in an oil-exporting country, as the country's income will increase. The consequence of the income increase is expected to be a rise in expenditure and investments, which in turn creates greater productivity and lower unemployment. Stock markets tend to respond positively in such event.

For an oil-importing country, any oil price increase will tend to have the opposite results; see LeBlanc and Chinno (2004) and Hooker (2002). Oil price increase will lead to higher cost of productions, as oil is one of the most important production factors (Arouri and Nguyen, 2010; Backus and Crucini, 2000; Kim and Loungani, 1992). The increase cost will be transferred to the consumers, which will, in turn, lead to lower demand and thus consumer spending, due to higher consumer prices; see for example, Bernanke (2006), Abel and Bernanke (2001), Hamilton (1996), Hamilton (1988a, 1988b) and Barro (1984). Lower consumption could lead to lower production and thus increased unemployment; see Lardic and Mignon (2006), Brown and Yucel (2002) and Davis and Haltiwanger (2001). Stock markets would react negatively in such case; see Sadorsky (1999), and Jones and Kaul (1996).

However, we should not lose sight of the fact that oil price shocks could affect stock markets due to the uncertainty that they create to the financial world, depending on the nature of the shock (demand-side or supply-side). In this case stock markets could respond positively to an oil price shock, which originates from the demand side, and negatively if the shock originates from the supply side.

Having briefly discussed the possible transmission mechanisms of an oil price shock to the stock market, we proceed to the analysis of the previous studies in this area.

Mounting evidence suggests a negative relationship between oil prices and stock market returns. Jones and Kaul (1996) were the first to reveal the negative impact of oil price on stock markets, which occurs due to the fact that oil price, is a risk factor for stock markets. Other authors, such as Filis (2010), Chen (2009), Miller and Ratti (2009), Nandha and Faff (2008), O'Neill et al. (2008), Park and Ratti (2008), Driesprong et al. (2008), Ciner (2001) and Gjerde and Sættem (1999) have also provide evidence towards such a negative relationship. Sadorsky (1999) argued that oil price volatility has also an impact on stock returns. Oberndorfer (2009) seconds that opinion in his study on the effect of oil price volatility on European stock markets.

Specifically for the oil-exporting countries, Arouri and Rault's (2009) conclusion suggested that a positive oil price shock has a positive impact on the stock market performance. Similar results were documented by Bashar (2006). Hammoudeh and Aleisa (2004), on the other hand, found a bidirectional relationship between oil prices and stock markets, in oil-exporting countries.

Other studies concentrate their interest in the investigation of the oil price shock origin, i.e. demand-side or supply-side shock. These studies include Hamilton (2009), Lescaroux and Mignon (2008), Barsky and Kilian (2004) and Terzian (1985). The origin of an oil price shock is an important component when studying the relationship between oil prices and stock markets. In particular, Lescaroux and Mignon (2008) suggest that supply-side shocks could be related to higher oil price volatility, although it may not be the only reason. Demand-side shocks also justify high oil price volatility. In addition, Hamilton (2009) argued that demand-side shock deriving from industrialization of countries such as China could have a significant impact. He also voiced the opinion that lack of immediate response of oil-supply to a large scale increase in oil-demand could result to a demand-side shock. Kilian and Park (2009) advocated that demand-side oil price shocks influence stock prices more than the supply-side oil price shocks. Demand-side oil price shocks exercise a negative influence on stock prices due to the *precautionary demand for crude oil*, which echoes the

uncertainty of future oil supply availability. However, they suggested that if the demand-side oil price shock is driven by global economic expansion, then higher oil prices will cause a positive effect on stock prices, which is in line with Hamilton's (2009) views.

All that said, a wealth of literature suggests that there is no relationship between oil price and stock markets; see for example Cong et al. (2008), Haung et al. (1996) and Chen et al. (1986). Specifically for oil-importing countries, Al-Fayoumi (2009) found no evidence that oil price shocks affect the stock markets. Other authors appose the view that oil prices do not seem to have any effect in the economy after the 1980s (Lescaroux and Mignon, 2008; Nordhaus, 2007; Blanchard and Gali, 2007; Bernanke et al., 1997; Hooker 2002, 1996). Miller and Ratti (2009) concluded that oil price effects are insignificant after 1999 due to oil price bubbles which have taken place since the early 2000. Jammazi and Aloui (2010) and Apergis and Miller (2009) painted the same picture suggesting that oil prices do not affect stock market performance. Such conclusions could originate from the fact that oil prices are not any more a significant source for economic downturn, as was suggested by Hamilton (1983). Nowadays, the majority of the countries have turned the focus of their monetary policy on inflation stability putting an effort to the absorption of any shocks that could cause inflationary pressures - e.g. oil price shocks - (Lescaroux and Mignon, 2008; Blanchard and Gali, 2007; Bernanke et al., 1997). Furthermore, due to increased productivity, investments and renewable energy sources, firms are able to absorb increased production input costs without the need of price increases (International Energy Agency, 2006). Wage flexibility plays an important role on the reduced impact of oil price shocks, as well. Nordhaus (2007) suggested that due to the greater wage flexibility in some countries, responses to oil price shocks tend to be more neoclassical rather than Keynesian. Similar evidence was adduced by Blanchard and Gali (2007). Neoclassical theory, in contrast to the Keynesians, argues that effect on output is much smaller and thus oil price shocks should have minimum impact in the economy. Hence, according to this theory, oil price shocks should have small or no impact on stock markets today, as well.

4. Model and data description

4.1. Model description

It should be mentioned that the present study focuses on investigating the undeviating time-varying correlation between stock market and oil prices. Thus, we do not intend either to estimate a system that isolates oil price shocks or to investigate what other exogenous

variables might have changed and which other endogenous variables might have taken the oil price pressure.

In the paragraphs follow, the model framework of our study is presented. Let the $(n \times 1)$ vector $\{\mathbf{y}_t\}$ refer to the multivariate stochastic process to be estimated. In the present model framework, $n=2$ and $\mathbf{y}_t = \begin{pmatrix} y_{1,t} \\ y_{2,t} \end{pmatrix}$, where $y_{1,t}$ denotes the stock index log-returns and $y_{2,t}$ denotes the log-returns of the oil prices (log-returns are first difference of logarithmic prices). The innovation process for the conditional mean $\boldsymbol{\varepsilon}_t \equiv \mathbf{y}_t - \boldsymbol{\mu}_t$ has an $(n \times n)$ conditional covariance matrix $V_{t-1}(\mathbf{y}_t) \equiv \mathbf{H}_t$:

$$\begin{aligned} \mathbf{y}_t &= \boldsymbol{\mu}_t + \boldsymbol{\varepsilon}_t \\ \boldsymbol{\varepsilon}_t &= \mathbf{H}_t^{1/2} \mathbf{z}_t \\ \mathbf{z}_t &\sim f(\mathbf{z}_t; \mathbf{0}, \mathbf{I}, \nu) \\ \mathbf{H}_t &= \sigma(\mathbf{H}_{t-1}, \mathbf{H}_{t-2}, \dots, \boldsymbol{\varepsilon}_{t-1}, \boldsymbol{\varepsilon}_{t-2}, \dots), \end{aligned} \quad (1)$$

where $E_{t-1}(\mathbf{y}_t) \equiv \boldsymbol{\mu}_t$ denotes the mean of \mathbf{y}_t conditional the available information at time $t-1$, I_{t-1} . \mathbf{z}_t is an $(n \times 1)$ vector process such that $E(\mathbf{z}_t) = \mathbf{0}$ and $E(\mathbf{z}_t \mathbf{z}_t') = \mathbf{I}$. $f(\mathbf{z}_t; \mathbf{0}, \mathbf{I}, \nu)$ denotes the multivariate standardized Student-t density function:

$$f(\mathbf{z}_t; \mathbf{0}, \mathbf{I}, \nu) = \frac{\Gamma((\nu+n)/2)}{\Gamma(\nu/2)(\pi(\nu-2))^{n/2}} \left(1 + \frac{\mathbf{z}_t' \mathbf{z}_t}{\nu-2}\right)^{-\frac{\nu+n}{2}}, \quad (2)$$

where $\Gamma(\cdot)$ is the gamma function and ν is the degree of freedoms to be estimated, for $\nu > 2$. The multivariate Student-t distribution was first proposed in the estimation of multivariate ARCH models by Harvey et al. (1992) and Fiorentini et al. (2003). $\sigma(\cdot)$ is a positive measurable function of the lagged conditional covariance matrices and the innovation process. Student-t distribution allows to model the excess leptokurtosis which is not captured by the ARCH process (see Xekalaki and Degiannakis, 2010).

Engle (2002) introduced the Dynamic Conditional Correlation GARCH, or the DCC-GARCH, model. The DCC-GARCH can be successively estimated for large time-varying covariance matrices (moreover, it requires the estimation of less number of parameters than other multivariate GARCH models). It assumes that the covariance matrix can be decomposed such as:

$$\mathbf{H}_t = \boldsymbol{\Sigma}_t^{1/2} \mathbf{C}_t \boldsymbol{\Sigma}_t^{1/2}, \quad (3)$$

where $\Sigma_t^{1/2}$ is the diagonal matrix with the conditional standard deviations along the diagonal, i.e.:

$$\Sigma_t^{1/2} = \text{diag}(\sigma_{1,t}, \sigma_{2,t}, \dots, \sigma_{n,t}), \quad (4)$$

and C_t is the matrix of conditional correlations. The model is estimated in two steps. At the first step, the conditional variances, $\sigma_{i,t}^2$, for the $i=1, \dots, n$ assets, are estimated as Glosten et al.'s (1993) GJR(1,1) models:

$$\sigma_{i,t}^2 = a_{i,0} + a_i \varepsilon_{i,t-1}^2 + \gamma_i d(\varepsilon_{i,t-1} < 0) \varepsilon_{i,t-1}^2 + b_i \sigma_{i,t-1}^2, \quad (5)$$

where $a_{i,0}, a_i, \gamma_i, b_i$ are parameters to be estimated, $d(\cdot)$ denotes the indicator function (i.e. $d(\varepsilon_{t-i} < 0) = 1$ if $\varepsilon_{t-i} < 0$, and $d(\varepsilon_{t-i} < 0) = 0$ otherwise). The GJR model allows good news, ($\varepsilon_{t-i} > 0$), and bad news, ($\varepsilon_{t-i} < 0$), to have differential effects on the conditional variance (i.e. leverage effect). Therefore, good news has an impact of a_i , while bad news has an impact of $a_i + \gamma_i$.

At the second step, using the residuals resulting for the first stage, the conditional correlation is estimated. The time varying correlation matrix has the form:

$$C_t = Q_t^{*-1/2} Q_t Q_t^{*-1/2}. \quad (6)$$

The correlation matrix, $Q_t = (q_{i,j,t})$, is computed using

$$Q_t = (1-a-b)\bar{Q} + a(\mathbf{z}_{t-1}\mathbf{z}'_{t-1}) + bQ_{t-1}, \quad (7)$$

where \mathbf{z}_t are the residuals standardized by their conditional standard deviation, i.e.

$\mathbf{z}_t = (z_{1,t}, z_{2,t}, \dots, z_{n,t})' = (\varepsilon_{1,t} \sigma_{1,t}^{-1}, \varepsilon_{2,t} \sigma_{2,t}^{-1}, \dots, \varepsilon_{n,t} \sigma_{n,t}^{-1})'$, \bar{Q} is the unconditional covariance of the standardized residuals and $Q_t^{*-1/2}$ is a diagonal matrix composed of the square roots of the inverse of the diagonal elements of Q_t , i.e. $Q_t^{*-1/2} = \text{diag}(q_{1,1,t}^{-1/2}, q_{2,2,t}^{-1/2}, \dots, q_{n,n,t}^{-1/2})$. For technical information about the estimation of the model you are referred to Xekalaki and Degiannakis (2010).

The detailed presentation of DCC-GARCH-GJR model with Student-t distribution for $n = 2$ dimensions follows:

$$\begin{aligned}
\begin{pmatrix} y_{1,t} \\ y_{2,t} \end{pmatrix} &= \begin{pmatrix} b_{1,0} \\ b_{2,0} \end{pmatrix} + \begin{pmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{pmatrix} \\
\begin{pmatrix} \varepsilon_{1,t} \\ \varepsilon_{2,t} \end{pmatrix} &= \mathbf{H}_t^{1/2} \begin{pmatrix} z_{1,t} \\ z_{2,t} \end{pmatrix} \\
\begin{pmatrix} z_{1,t} \\ z_{2,t} \end{pmatrix} &\sim f\left(\begin{pmatrix} z_{1,t} \\ z_{2,t} \end{pmatrix}; \begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}, \nu\right) \\
f\left(\begin{pmatrix} z_{1,t} \\ z_{2,t} \end{pmatrix}; \begin{pmatrix} 0 \\ 0 \end{pmatrix}, \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}, \nu\right) &= \frac{\Gamma((\nu+n)/2)}{\Gamma(\nu/2)(\pi(\nu-2))^{n/2}} \left(1 + \frac{\begin{pmatrix} z_{1,t} \\ z_{2,t} \end{pmatrix}' \begin{pmatrix} z_{1,t} \\ z_{2,t} \end{pmatrix}}{\nu-2} \right)^{-\frac{\nu+n}{2}} \\
\mathbf{H}_t &= \boldsymbol{\Sigma}_t^{1/2} \begin{pmatrix} q_{1,1,t}^{-1/2} & 0 \\ 0 & q_{2,2,t}^{-1/2} \end{pmatrix} \mathbf{Q}_t \begin{pmatrix} q_{1,1,t}^{-1/2} & 0 \\ 0 & q_{2,2,t}^{-1/2} \end{pmatrix} \boldsymbol{\Sigma}_t^{1/2} \\
\boldsymbol{\Sigma}_t^{1/2} &= \begin{pmatrix} \sqrt{a_{1,0} + a_1 \varepsilon_{1,t-1}^2 + \gamma_1 d(\varepsilon_{1,t-1} < 0) \varepsilon_{1,t-1}^2 + b_1 \sigma_{1,t-1}^2} & 0 \\ 0 & \sqrt{a_{2,0} + a_2 \varepsilon_{2,t-1}^2 + \gamma_2 d(\varepsilon_{2,t-1} < 0) \varepsilon_{2,t-1}^2 + b_2 \sigma_{2,t-1}^2} \end{pmatrix}, \\
\mathbf{Q}_t &= (1-a-b)\bar{\mathbf{Q}} + a \begin{pmatrix} z_{1,t-1} \\ z_{2,t-1} \end{pmatrix} \begin{pmatrix} z_{1,t-1} \\ z_{2,t-1} \end{pmatrix}' + b \mathbf{Q}_{t-1}
\end{aligned} \tag{8}$$

4.2. Data description

In this study, we use monthly data for oil prices and stock market indices. The sample consists of three oil-exporting countries (Canada, Mexico and Brazil) and three oil-importing countries (US, Germany and Netherlands). The stock market indices are: S&P/TSX 60 (Canada), MXICP 35 (Mexico), Bovespa Index (Brazil), Dow Jones Industrial (USA), DAX 30 (Germany) and AEX General Index (Netherlands). To set the sample, the criteria follow should have been satisfied. The first criterion was that all countries should have a well established stock market. Secondly, the selected countries are in the top 20 oil-importers and oil-exporters. The third criterion was the mixture of traditional stock markets and developing stock markets.

US are the largest crude oil importer with imports of 11 billion barrels per day (bpd) in 2008, which accounted for 63.2% of the domestic consumption. Germany and Netherlands imported a significantly higher proportion of their domestic consumption. In particular Germany imported in 2008 112.8% of its domestic consumption (or nearly 3 billion bpd). Netherlands, on the other hand, imported 2.7 million bpd, which was equal to 100% of their domestic consumption.

Regarding the oil exporting countries, Canada exported 2.4 million bpd and that is equal to the 3.6% of the world total crude oil exports. Mexico exported about 1.3 million bpd

in 2008, which accounts for the 2.1% of the world total crude oil exports. Finally, Brazil exported almost half a million bpd in 2008.

The Brent⁴ crude oil index is used as it accounts for the 60% of the world oil daily production (Maghyreh, 2004). The data range from January 1987 to September 2009. However, for Mexico the data used are from January 1988 to September 2009. All prices from both markets (oil and stock) are expressed in dollar terms and have been extracted from *Datastream*[®] Database.

The DCC-GARCH model was estimated for higher sampling frequencies, i.e. weekly and daily sampling frequencies, but the results are qualitatively similar. However, for purposes of illustration the monthly sampling frequency is proposed⁵.

5. Empirical findings

5.1. Oil price and stock market movements

Figure 2 plots the stock market indices over time. Taking into consideration the peaks and troughs of oil prices (see Section 2) and the events that have taken place during our period of study (see Tables 1 and 2), we can initiate a preliminary discussion on the relationship between oil and stock market prices.

[FIGURE 2 HERE]

[TABLE 2 HERE]

Primarily, we observe that stock markets do not always move at the same directions with oil prices. For example, during 1990 oil prices exhibited a peak, whereas the majority of the stock markets showed a stable performance, if not a declining one. In addition, during 1997-1998 an oil price decrease is observed, whereas the majority of the stock markets were exhibiting an increase in their index levels. Furthermore during the period 1999-2000, when we observe another period of oil price increases (reaching a peak in late 2000), stock market prices showed an increase, as well. Stock market showed a decreasing pattern during the period 2000-2003. For the first half of this period, oil prices suffered a decrease, as well. However, for the second half of the 2000-2003 period oil prices were increasing constantly. In addition, the period 2004 until mid-2006 is characterised mainly by a continuous oil price increase, as well as, increased stock market prices. During mid-2006 until early 2007, when an oil price trough is observed, stock markets also exhibited a decrease in their price levels.

⁴ WTI oil prices were also considered but the results are qualitatively similar.

⁵ Daily prices produce more volatile figures, as expected, although there are specific periods where a peak or a trough in correlation coefficient is clear.

Moreover, during 2007 until mid-2008 and during early 2009 until September 2009, both oil prices and stock market are bullish. Finally, during the period mid-2008 and early 2009, both oil and stock market prices experienced a bearish performance.

The visual inspection of the Figures does not provide a clear distinction between stock market performance and oil prices on oil-importing and oil-exporting countries.

We should not lose sight of the fact that the above analysis is only preliminary. The actual conclusions for the dynamic correlation between oil prices and stock market performance should be based on the analysis of the DCC-GARCH model presented in the following section. The dynamic correlation findings will describe more explicitly the co-movements between oil prices and stock market indices.

5.2. Dynamic correlation findings

5.2.1. Contemporaneous correlations

The graphs resulted from the time-varying correlation coefficients as computed from equation (8) between each stock market index and the Crude oil prices are presented in Figure 3.⁶

[FIGURE 3 HERE]

During the period 1990-1991, we observe that all stock markets, apart from the Brazilian one, show a considerable negative correlation with oil prices. This is the period dominated by changes in the precautionary demand for crude oil, a period when Iraq invaded Kuwait and, in turn, US invaded Iraq. In addition, it is a period when the Soviet Union collapses. Although this oil crisis was considered as a mild one, the effects were significant, as, according to Taylor (1993), the reaction by the government regulations were not in a flexible manner.

Furthermore, the Asian economic crisis, which took place in mid-1997 and early 1998, did not produce any significant positive or negative correlation between oil prices and stock markets, for most of the markets under consideration. All stock markets, apart from US, exhibited a low positive correlation with oil prices, during the Asian Crisis. Exemption was the German stock market, which showed a moderate positive correlation during this period. The Asian economic crisis created a negative aggregate demand-side oil price shock, driving

⁶ The estimated parameters are not reported, but they are available upon request. Moreover, the specification tests of the models, i.e. ARCH-LM test, autocorrelation tests of the standardized residuals, etc., which provide the adequacy of the DCC-GARCH model, are also available. The models were estimated in G@RCH 5.0 package for Ox Metrics[®]; for technical details about the estimation of the models see Laurent (2007).

oil prices at lower levels. The majority of stock markets in that period were also experienced a small decline or a stable performance.

Continuing along the time-line of events, we observe that for a period of six years, following the Asian economic crisis, i.e. 1998-2004, all stock market from oil-exporting countries and the Netherlands stock market exhibit a positive correlation with oil prices (apart for the mid-2003, where correlation became weakly negative). During this period we have several oil production cuts by OPEC (especially in the period 1998-1999), decisions for oil production increases (mainly in 2000 due to the rapid growth of the housing market) and the PdVSA workers' strike that took place in Venezuela (in 2002). In addition, we experienced the September 2001 terrorist attack in the World Trade Centre (WTC) in US. The German and the US stock markets had a positive correlation with oil prices at the period of the 9/11 and during 2000, as well.

However, during the period 1998-2004, we had another major event that caused turbulence in oil and stock prices. That was the second war in Iraq, which started in March 2003. During the second invasion of US troops in Iraq, all stock markets, apart from the Mexican market, were exhibiting a negative correlation with oil prices, although weak. During the second war in Iraq, oil prices increase significantly but at the same time it caused world stock markets to react negatively.

Inside the period 1998-2004, a peak in correlation coefficient is observed around the year 2000 for all countries. This high positive correlation between oil and stock market prices was initiated because of the high demand for oil due to the rapid increase in the housing market and construction industry, which was a result of decreasing interest rates worldwide.

The next period of interest, is the period 2006 until mid 2008 which is characterised as a period when oil prices increased significantly due to rising demand, mainly by China. The correlation coefficient showed an increasing and positive pattern for all countries. This aggregate demand-side oil price shock was expected to have a positive effect on stock markets (both in oil-importing and oil-exporting countries) as it signals an increase in world trade (mainly dominated by China). This finding is in line with Hamilton (2009) and Kilian and Park (2009) findings, who suggested that aggregate demand-side oil price shocks, originated by world economic growth, have a positive impact on stock prices.

During the mid-2008 and early 2009 the pattern shows that correlation coefficient for all stock markets is still in the positive area. The main event at this period is the global financial crisis initiated from the export of US toxic mortgages to the rest of the world, as asset-backed securities (Stiglitz, 2009), which can be regarded as an aggregate demand-side

oil price shock (International Energy Agency, 2009). The positive correlation between oil and stock market prices can be explained by the fact that such crisis caused stock markets to enter bearish territories and caused oil prices to decline heavily, as well.

We should make clear though that there are only three periods of noteworthy positive or negative correlation between oil prices and stock markets. These are the periods 1990-1991 (precautionary demand oil price shock – negative correlation), early 2000 until mid-2000 (aggregate demand-side oil price shocks – positive correlation) and 2007-2008 (aggregate demand-side oil price shock – positive correlation).

In addition, there is not a period where some differences in the correlation between oil and stock market prices for oil-importing and oil-exporting countries could be observed. The explanation of such finding lies to the events that took place and caused changes in oil and stock market prices.

The first war in Iraq and the collapse of the Soviet Union caused a significant turbulence and uncertainty in world markets, regardless the status of the stock market (oil-importing or oil-exporting). Furthermore, the Asian economic crisis caused a significant decrease in oil demand and at the same time uncertainty in all world stock markets. In addition, the boom that the housing market experienced in 2000 created a positive environment for world markets and at the same time a high demand for oil, driving the prices of both markets in higher levels. The 9/11 terrorist attack and the second war in Iraq also created significant uncertainty in all economies, causing similar movements in their stock markets and thus similar correlation with oil prices (i.e. negative). In addition, the Chinese growth and its impact in the world trade caused euphoria in all stock markets regardless the country of origin. Similarly, the last world financial crisis influenced all stock market similarly and thus their correlation with oil prices was similar.

Thus, two main findings can be extracted from our analysis. Oil price shocks in periods of world turmoil or during fluctuations of the global business cycle (downturn or expansion) seem to have a significant impact on the relationship between oil and stock market prices, regardless the status of the market (i.e. belonging to an oil-importing or oil-exporting country). However, all other oil price shocks originated by OPEC's productions cuts, hurricanes etc., do not seem to have a significant impact on the correlation between oil and stock markets. Moreover, important precautionary demand side oil price shocks (i.e. first and second war in Iraq, 9/11 terrorist attack) tend to cause a negative correlation between oil and stock markets, whereas aggregate demand-side oil price shocks (Asian crisis, Housing market boom, Chinese economic growth, and the latest global financial crisis) cause a

significant positive correlation between stock market prices and oil prices. This finding is partly in line with the evidence provided by Hamilton (2009) and Kilian and Park (2009).

Overall, the origin of the shock seems to be an important determinant of the correlation magnitude between oil prices and stock markets, as long as the oil shocks originate from major events of world turmoil, such as wars or changes in the phase of the global business cycle. Supply-side shocks do not affect the relationship between stock markets and oil prices. A summary of the findings is provided in Table 3.

[TABLE 3 HERE]

The magnitude of the correlation is another issue of interest. Overall, evidence suggest that the origin of the shock does not have an impact on the magnitude of the correlation. On the contrary, the main determinant of the correlation magnitude is the event that caused changes in oil and stock market prices. Thus, the aggregate demand-side shocks experienced in 1997-1998 and 2007-2008 and the precautionary demand shock experienced in 1990-1991 generated higher correlation coefficients, in absolute terms, than any other supply-side, demand-side or precautionary demand shocks documented earlier.

5.2.2. Lagged correlations

Market participants, mainly, are interested in exploiting the ability of one market to provide information for the future movement of another market. In the previous section, the contemporaneous correlation between the oil price and the stock price was investigated. In the present paragraph, we seek to investigate whether the lagged movements to energy market interact to shocks to asset market.

Therefore, the vector of the dependent variable is denoted as $\mathbf{y}_t = \begin{pmatrix} y_{1,t} \\ y_{2,t-1} \end{pmatrix}$.⁷ In other words, the time varying correlation between asset market log-returns of current month and energy market log-returns of previous month is explored. Findings of the lagged time-varying correlation show that in almost all events under consideration (i.e. the Iraq invasion in Kuwait, the first war in Iraq, the collapse of the Soviet Union, the Asian economic crisis, the housing boom, the 9/11 terrorist attack, the second war in Iraq and the Chinese economic growth), the correlation between the lagged oil prices and current stock prices is negative for all countries, regardless their status (i.e. oil-importing or oil-exporting). The only event that

⁷ The model framework, presented in equation (8), remains the same.

exhibits a positive correlation is the latest global financial crisis in 2008 (see Figure 4). These findings signify the importance of oil prices as risk factor for stock markets.

[FIGURE 4 HERE]

Magnitude-wise it is evident that the major precautionary demand shocks and the aggregate demand-side shocks generate the highest correlation figure (in absolute terms). Supply-side shocks do not seem to influence the correlation between the lagged oil prices and the current stock prices. This finding is in line with the conclusions that were generated in the contemporaneous correlations section.

[TABLE 4 HERE]

6. Conclusion

The paper investigates the time-varying correlation between stock market prices and oil prices for oil-importing and oil-exporting countries considering the origin of oil price shocks (i.e. aggregate demand-side, precautionary demand or supply-side). The dataset consists of monthly stock and oil prices from three oil-exporting countries (Canada, Mexico and Brazil) and three oil-importing countries (US, Germany and Netherlands), from 1987 to 2009.

The conditional correlation is estimated following Engle's (2002) DCC-GARCH model, where the conditional variances are estimated with Glosten's et al. (1993) GJR model.

The study provides evidence that time-varying correlation of oil and stock prices do not differ for oil-importing and oil-exporting economies. This can be explained by two facts. Firstly, aggregate demand side oil price shocks due to the fact that are caused by fluctuations in the global business cycle are expected to influence all stock markets in the same fashion. The finding that the precautionary demand side oil price shocks tend to influence oil-importing and oil-exporting countries in the same way can be attributed to the fact that the oil sector in the examined oil-importing countries is rather small that the effects of the uncertainty of any future crude oil supply shortages, considering the future crude oil demand, are bare minimum.

However, the correlation changes in respond to the origin of the oil price shocks in periods of world turmoil or changes in the phase of the global business cycle. In particular, precautionary demand shocks, which were caused by wars or terrorist attacks and aggregate demand-side shocks caused by fluctuations of the world business cycle (i.e. Asian crisis, housing market boom, Chinese growth, global financial crisis) tend to be influencing the correlation between oil and stock market prices in much greater extent compared to supply-side shocks originated by OPEC's productions cuts, hurricanes etc.

Moreover, the correlation between asset market log-returns of current month and energy market log-returns of previous month show that oil prices act as a risk factor for the stock markets, as in all events, but the global financial crisis of 2008, the correlation between the lagged oil prices and current stock prices is negative for all stock markets.

Our findings partially agree with the findings of other researchers, such as these by Miller and Ratti (2009), Lescaroux and Mignon (2008), Nordhaus (2007), Blanchard and Gali (2007), Bernanke et al. (1997), etc. These past researches concluded that for more than a decade now, oil prices do not affect stock prices.

We summarise the findings as follows: non-economic crises trigger a stronger negative link between oil prices and stock markets and on the other hand, economic crises or booms trigger a stronger positive link between oil prices and stock markets. Hence, precautionary demand shocks are causing negative correlation between oil and stock market prices, whereas aggregate demand-side shocks are causing a positive relationship. Supply-side shocks do not influence the relationship between oil and stock prices. Lagged oil prices act as a risk factor for the stock markets.

For further research, the time-varying correlation between oil prices and stock markets, taking into consideration macroeconomic variables as exogenous variables in the DCC-GARCH framework, is left. Such model will be able to capture any other exogenous variables that might have interact with oil and stock market prices.

Finally, it would be interesting to provide confidence bands for the time varying correlations, by using bootstrap or Monte Carlo simulations.

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Tables & Figures

TABLE 1. Oil Price Chronology from 1987 to 2009.

Part A. The main events took place in the period 1987-1997.

	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
January	OPEC meeting failure				US begin its attack to Iraq				Gabon withdraws from OPEC		
February											
March											
April								Nigerian oil workers go on strike resulting to a decrease in production		President Clinton approves the sale of crude oil from the Strategic Petroleum Reserve	
May											
June		OPEC raises production to 19.5 million bbl/d									
July											
August				Iraq invades Kuwait							
September											
October						Ecuador withdraws from OPEC					
November											OPEC agrees to an increase in its production ceiling
December					Soviet Union collapses						

Source: US Energy Information Administration.

Part B. The main events took place in the period 1998-2009.

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
January	Asian economic crisis				OPEC decides to cut quotas						Rising demand, low spare capacity	
February							OPEC decides to cut quotas at various meetings		Militant attacks in Nigeria shut down more than 600,000 bbl/d of oil production			
March		OPEC cuts quotas				War in Iraq						
April												
May	OPEC cuts quotas at various meetings		OPEC oil ministers agree on an increase in oil production								President Bush signs into law a bill that temporarily halts adding oil to the Strategic Petroleum Reserve	
June												
July												
August								Hurricanes Katrina, Dennis and Rita strike				
September				9/11 Attacks			Hurricane Ivan strikes				Hurricane Gustav strikes	
October												
November							OPEC decides to cut quotas at various					
December					PdVSA Strike in Venezuela						OPEC decides to cut quotas	

Source: US Energy Information Administration.

Table 2: Main events and their corresponding oil price shock origin.

Event	Year	Oil price shock origin
Iraq Invasion in Kuwait	1990	Precautionary demand
First war in Iraq	1991	Precautionary demand
Collapse of the Soviet Union	1991	Precautionary demand
Asian Economic Crisis	1997	Aggregate demand side
Several oil production cuts by OPEC	1998-1999	Supply side
Housing market boom	2000	Aggregate demand side
9/11 terrorist attack in US	2001	Precautionary demand
PdVSA worker's strike	2002	Supply side
Second war in Iraq	2003	Precautionary demand
Chinese economic growth	2006-2007	Aggregate demand side
Global financial crisis	2008	Aggregate demand side

Note: Events were tied up to specific oil price shocks origins according to Kilian's (2009) and Hamilton's (2009) findings.

TABLE 3. Summary of the findings – Contemporaneous correlations.

Event	Oil price shock origin	Correlation sign
Iraq Invasion in Kuwait/ First war in Iraq	Precautionary demand	negative
Asian economic crisis	Aggregate demand-side shock	positive
Housing market boom	Aggregate demand-side shock	positive
Second war in Iraq	Precautionary demand	negative
Chinese economic growth	Aggregate demand-side shock	positive
Global financial crisis	Aggregate demand-side shock	positive

TABLE 4. Summary of the findings – Lagged correlations.

Event	Oil price shock origin	Correlation sign
Iraq Invasion in Kuwait/ First war in Iraq	Precautionary demand	negative
Asian economic crisis	Aggregate demand-side shock	negative
Housing market boom	Aggregate demand-side shock	negative
Second war in Iraq	Precautionary demand	negative
Chinese economic growth	Aggregate demand-side shock	negative
Global financial crisis	Aggregate demand-side shock	positive

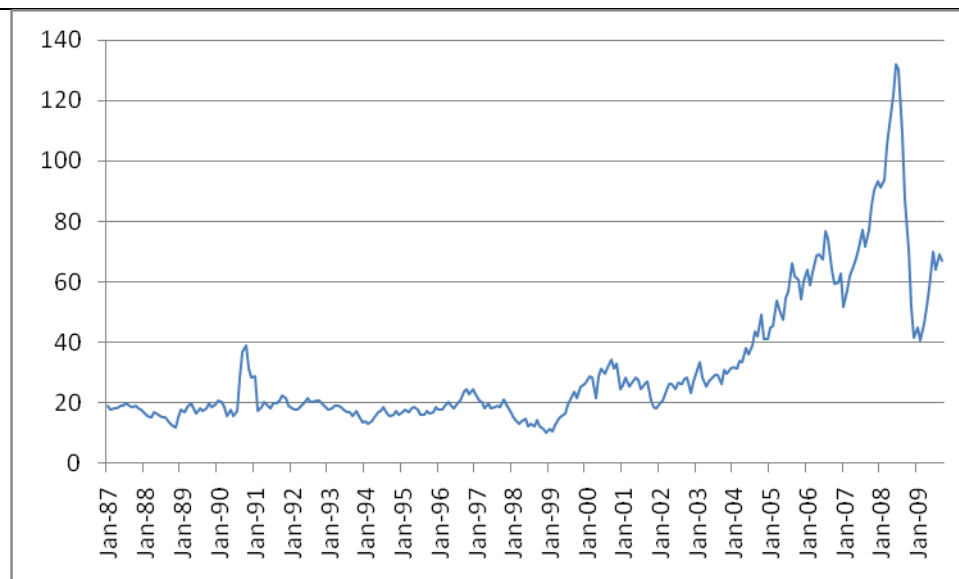
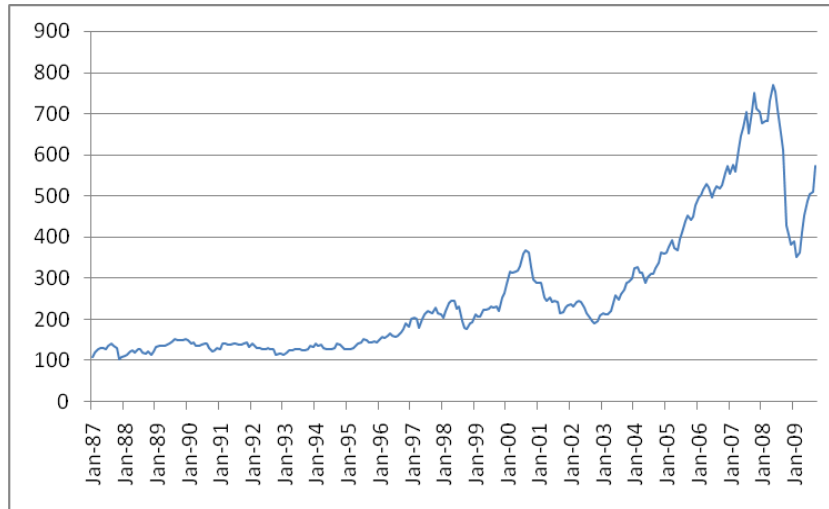
FIGURE 1. Brent crude oil price, in dollars, from January 1987 to September 2009.

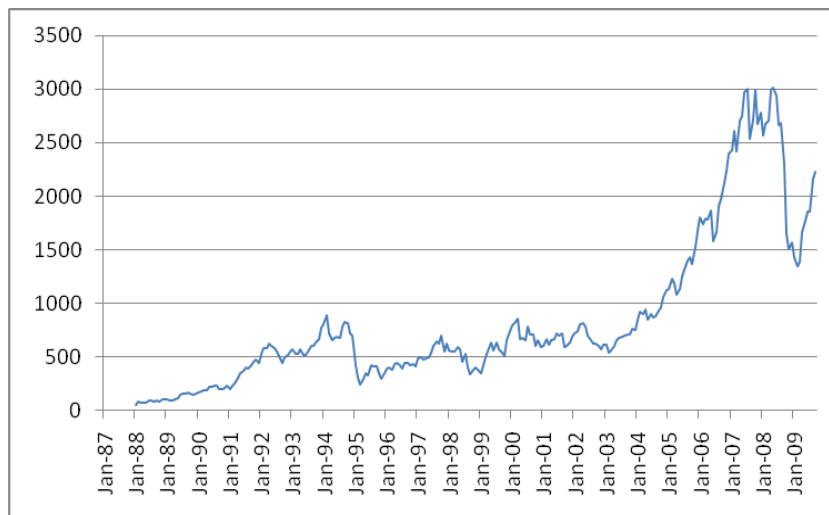
FIGURE 2: Stock Market Indices.

a) Oil Exporting Countries

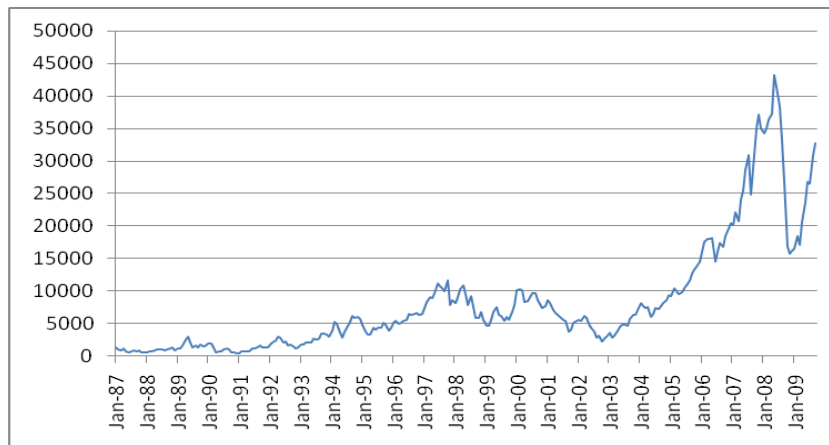
Canada: S&P/TSX 60 Index



Mexico: MXIPC 35 Index

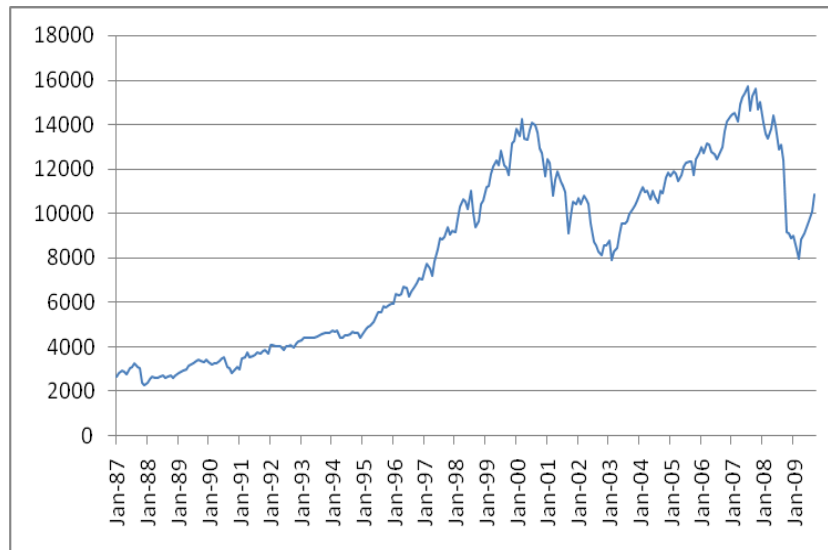


Brazil: Bovespa Index

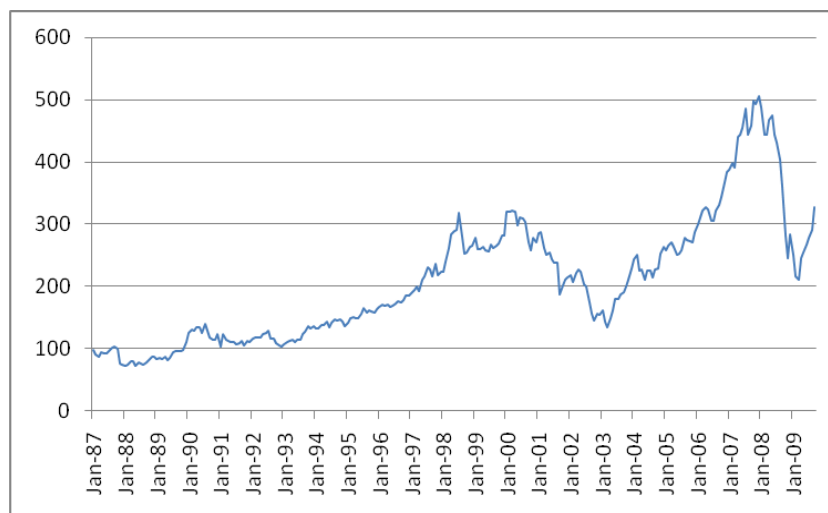


b) Oil Importing Countries

USA: Dow Jones Industrial Index



Germany: DAX 30 Index



Netherlands: AEX General Index

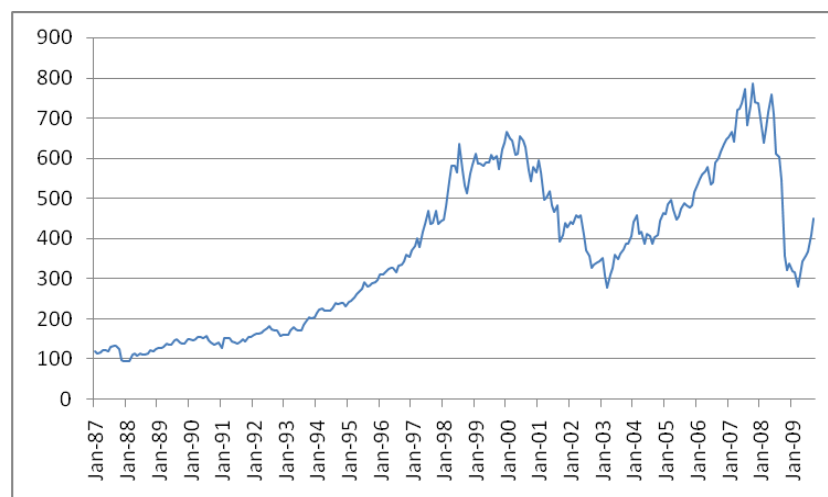


FIGURE 3: Dynamic Correlation between stock market index and the Crude oil price computed from the DCC-GARCH model with Student-t distribution as:

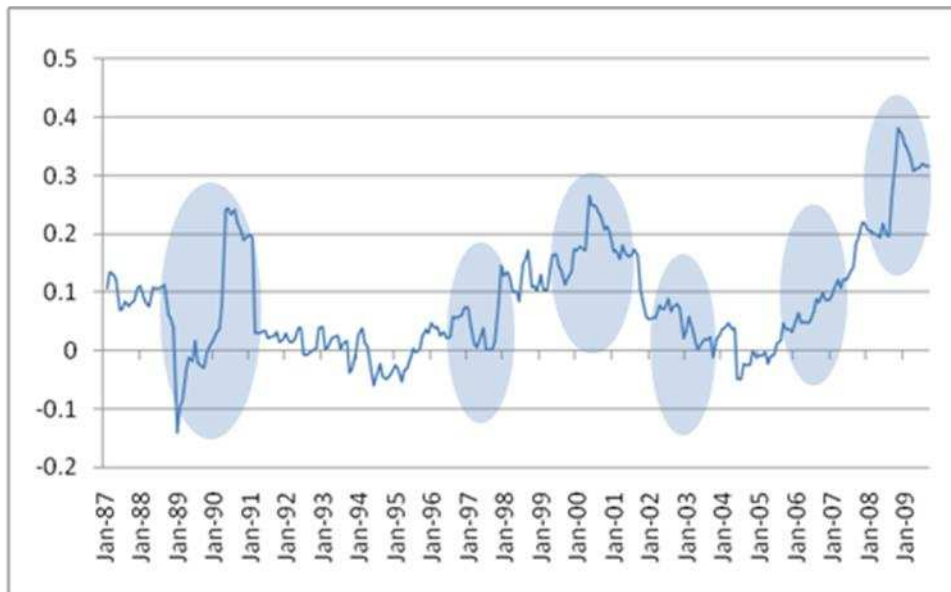
$$C_t = \mathbf{Q}_t^{*-1/2} \mathbf{Q}_t \mathbf{Q}_t^{*-1/2}, \text{ where}$$

$$\mathbf{Q}_t^{*-1/2} = \begin{pmatrix} q_{1,1,t}^{-1/2} & 0 \\ 0 & q_{2,2,t}^{-1/2} \end{pmatrix}$$

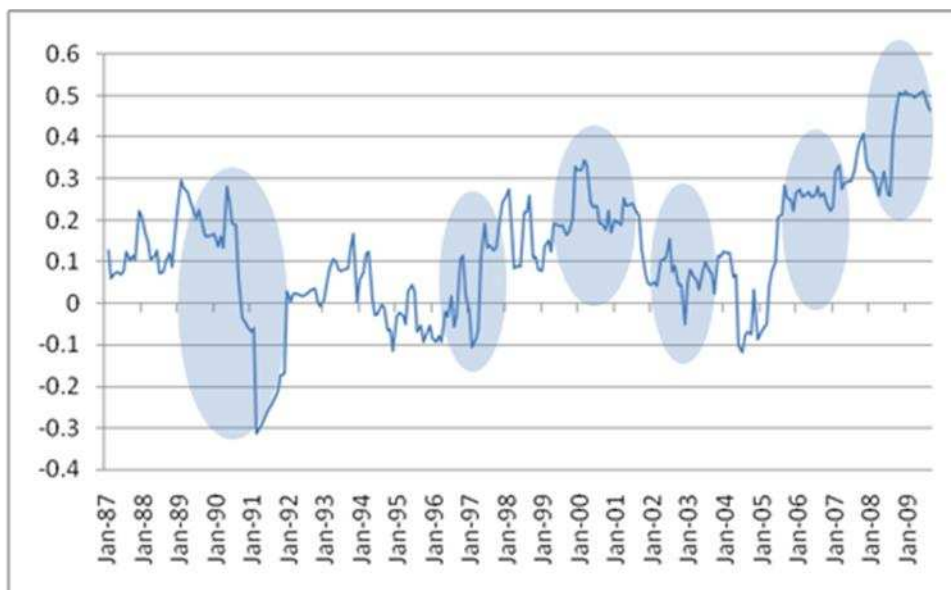
$$\mathbf{Q}_t = (1-a-b)\bar{\mathbf{Q}} + a \begin{pmatrix} z_{1,t-1} \\ z_{2,t-1} \end{pmatrix} \begin{pmatrix} z_{1,t-1} \\ z_{2,t-1} \end{pmatrix}' + b\mathbf{Q}_{t-1}$$

a) Oil Exporting Countries

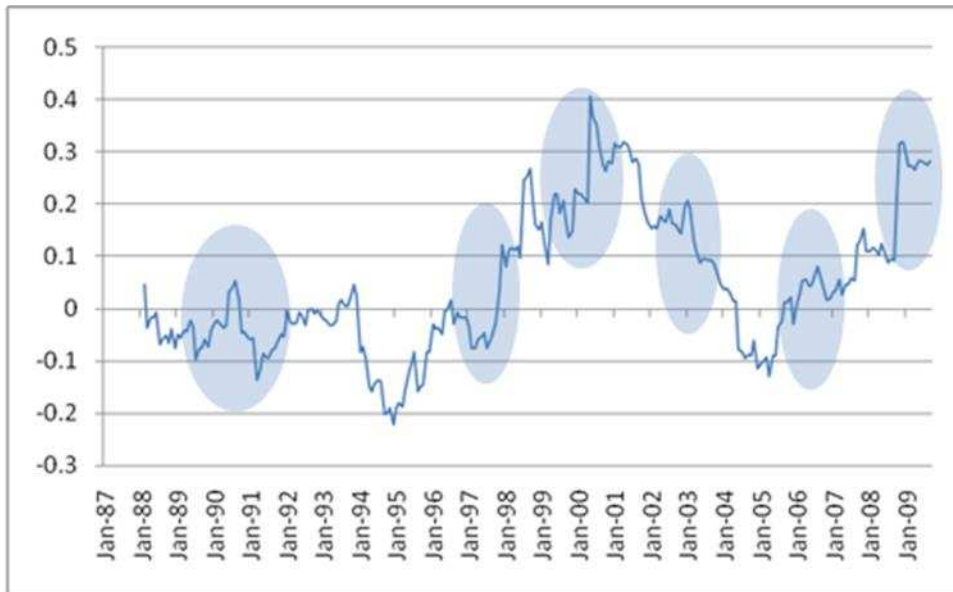
Time varying correlation between Brazilian stock market index (Bovespa) and crude oil.



Time varying correlation between Canadian stock market index (S&P/TSX 60) and crude oil.

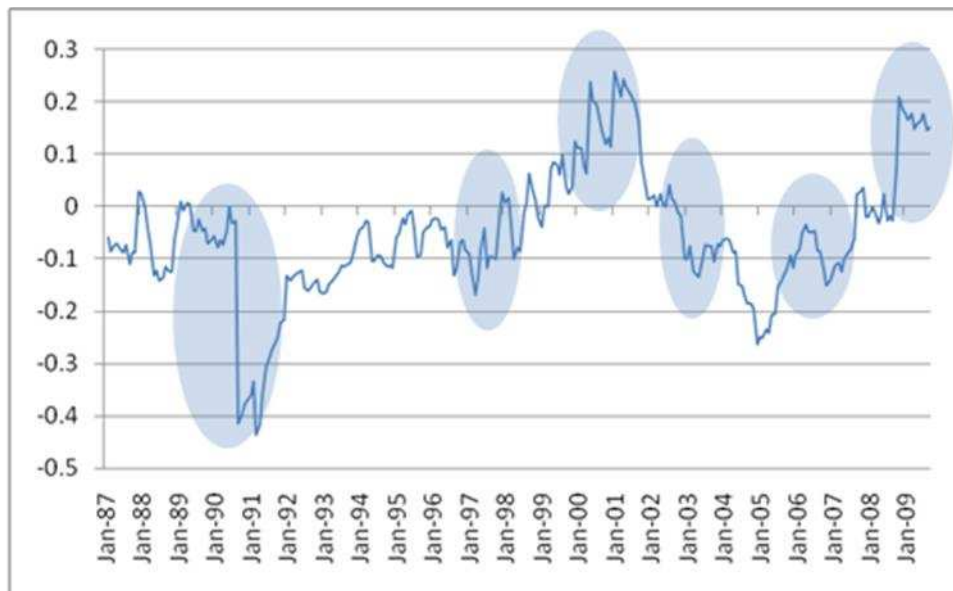


Time varying correlation between Mexican stock market index (MXIPC 35) and crude oil.

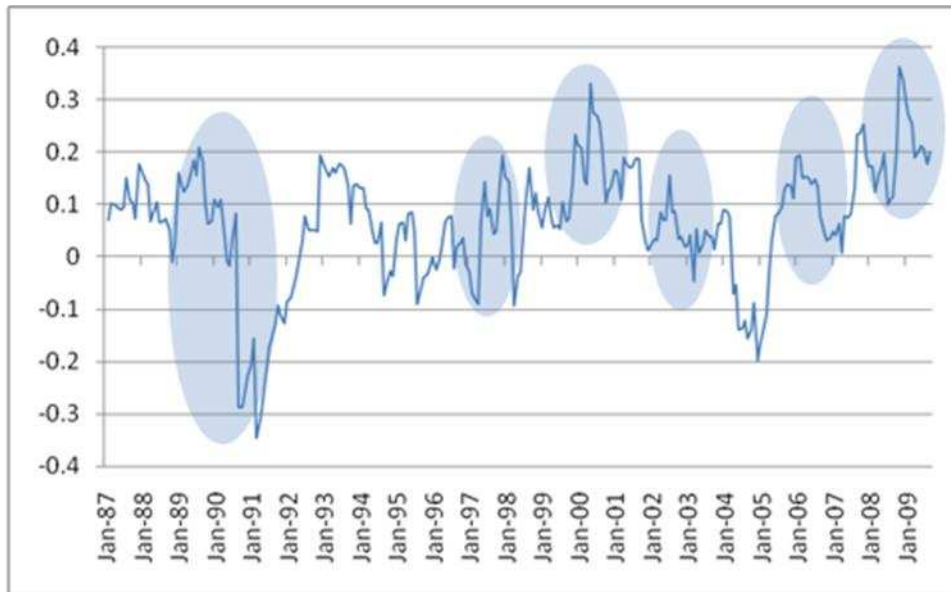


b) Oil Importing Countries

Time varying correlation between USA stock market index (Dow Jones Industrial) and crude oil.



Time varying correlation between Netherlands stock market index (AEX General) and crude oil.



Time varying correlation between German stock market index (DAX 30) and crude oil.

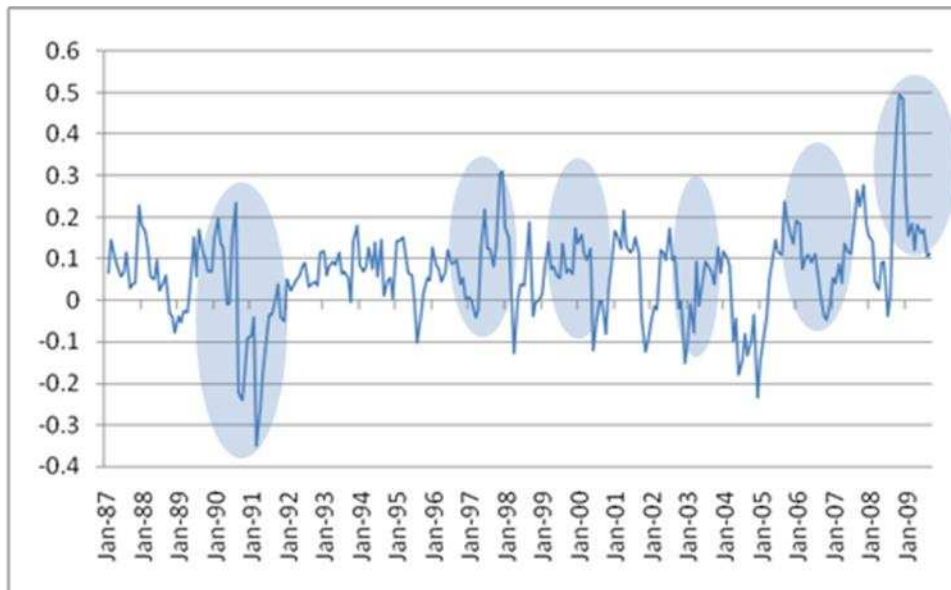


FIGURE 4: Dynamic Correlation between the lagged crude oil price and the stock market index, computed from the DCC-GARCH model with Student-t distribution as:

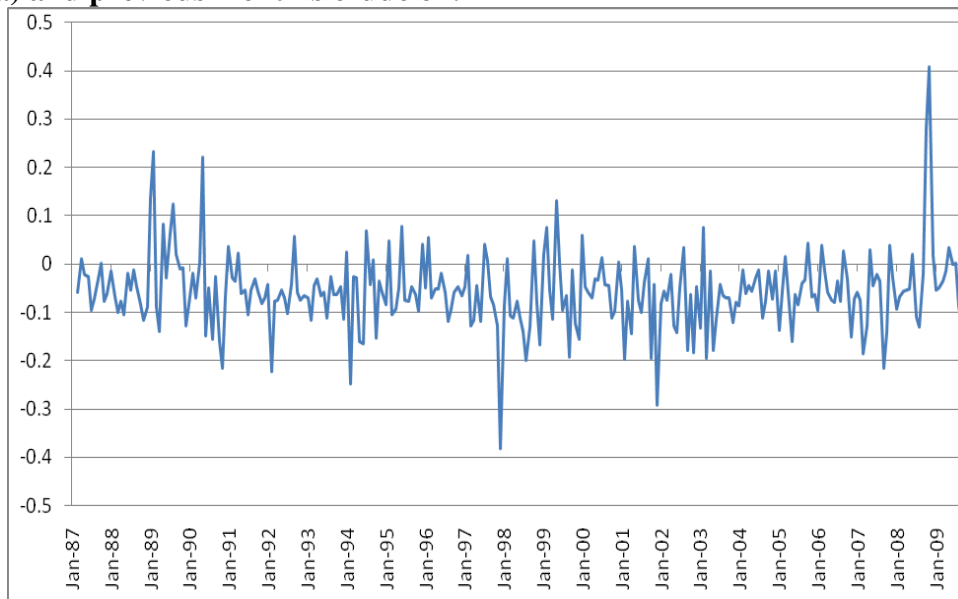
$$C_t = \mathbf{Q}_t^{*-1/2} \mathbf{Q}_t \mathbf{Q}_t^{*-1/2}, \text{ where}$$

$$\mathbf{Q}_t^{*-1/2} = \begin{pmatrix} q_{1,1,t}^{-1/2} & 0 \\ 0 & q_{2,2,t}^{-1/2} \end{pmatrix}$$

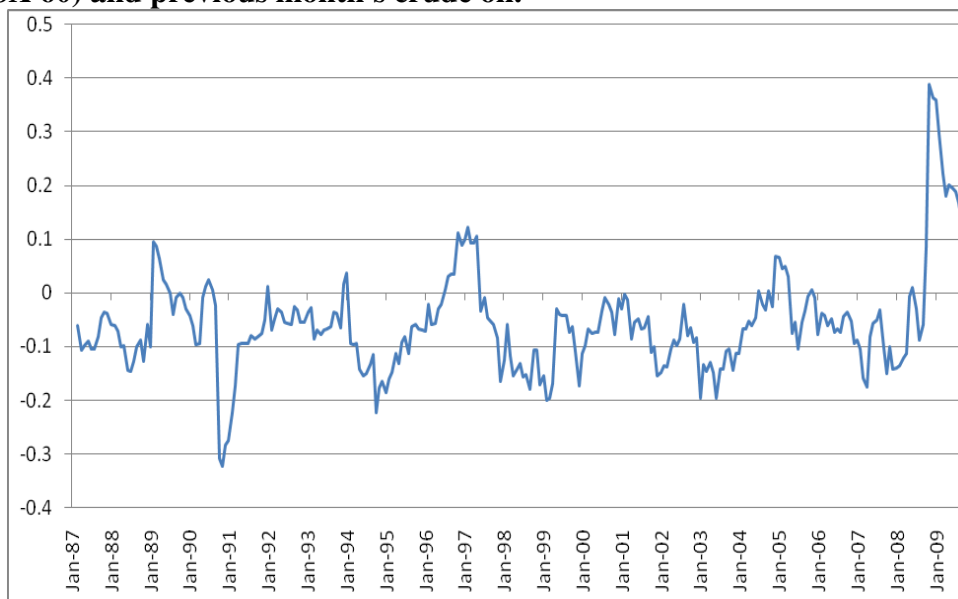
$$\mathbf{Q}_t = (1 - a - b)\bar{\mathbf{Q}} + a \begin{pmatrix} z_{1,t-1} \\ z_{2,t-1} \end{pmatrix} \begin{pmatrix} z_{1,t-1} \\ z_{2,t-1} \end{pmatrix}' + b\mathbf{Q}_{t-1}$$

a) Oil Exporting Countries

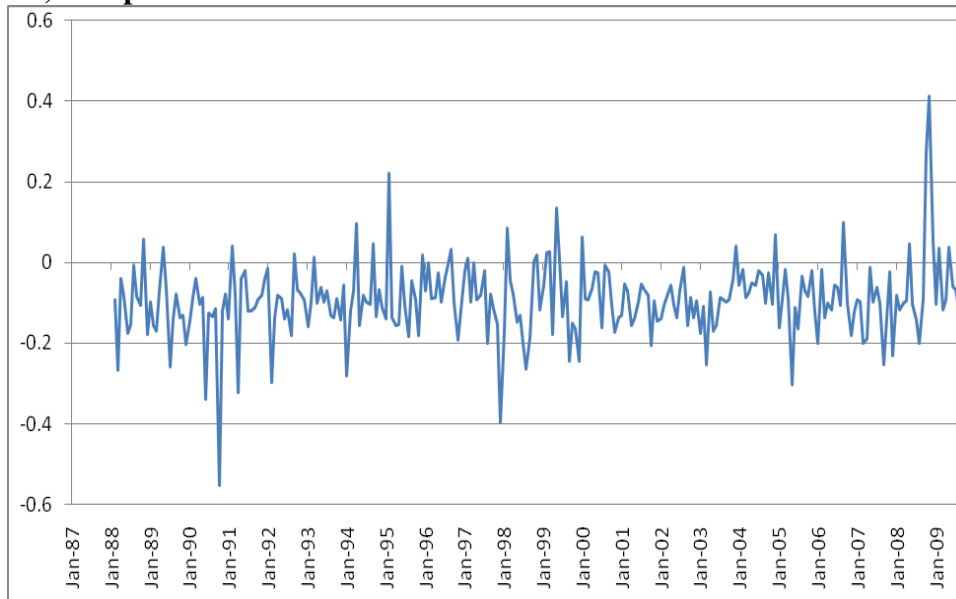
Time varying correlation between current month's Brazilian stock market index (Bovespa) and previous month's crude oil.



Time varying correlation between current month's Canadian stock market index (S&P/TSX 60) and previous month's crude oil.

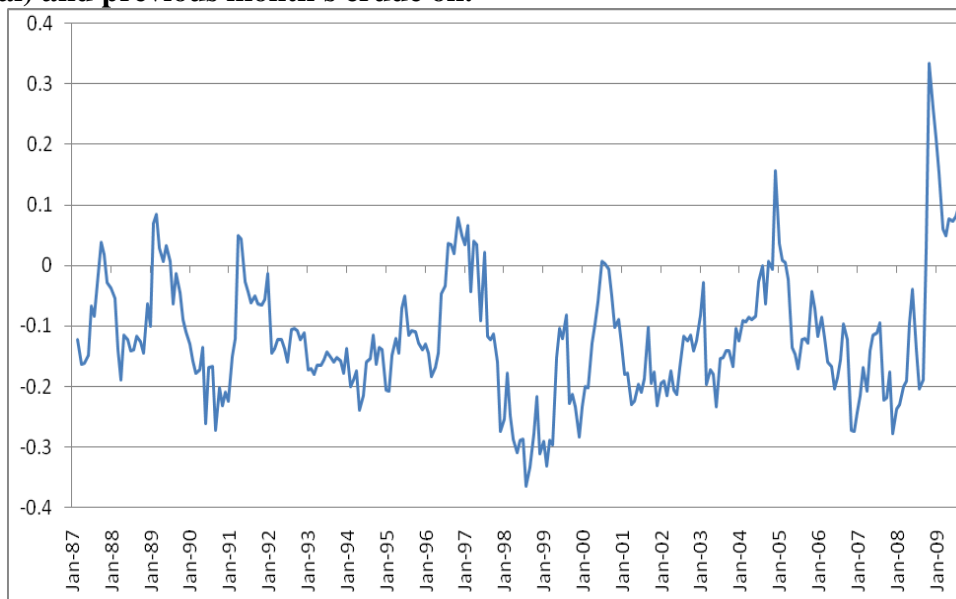


Time varying correlation between current month's Mexican stock market index (MXIPC 35) and previous month's crude oil.

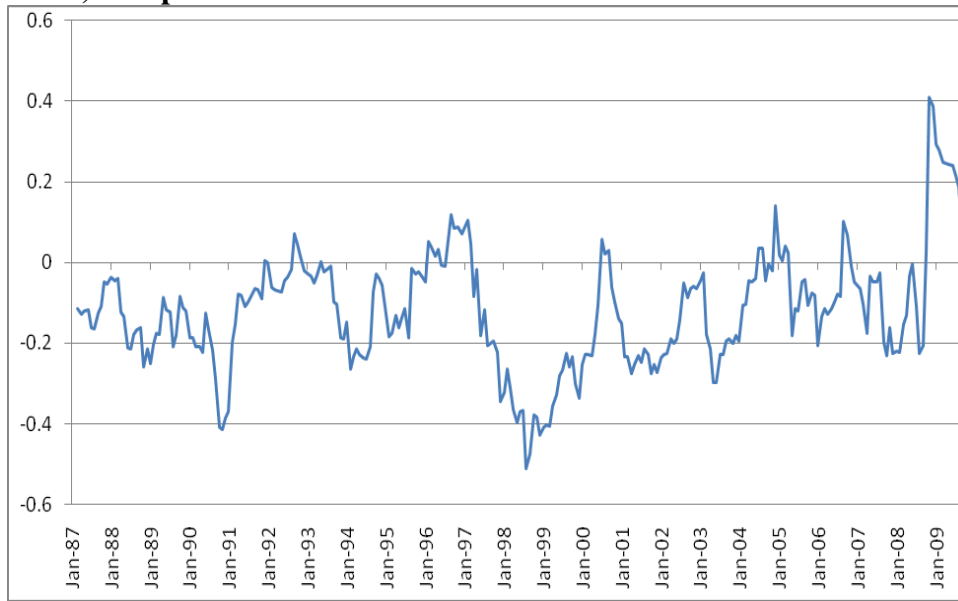


b) Oil Importing Countries

Time varying correlation between current month's USA stock market index (Dow Jones Industrial) and previous month's crude oil.



Time varying correlation between current month's Netherlands stock market index (AEX General) and previous month's crude oil.



Time varying correlation between current month's German stock market index (DAX 30) and previous month's crude oil.

