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Oil Prices and Stock Markets

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Abstract

We reviewed literature on the complex relationship between oil prices and stock market activity. The majority of papers surveyed study the impacts of oil markets on stock markets—little research in the reverse direction exists. In general, we find that the causal effects between oil and stock markets depend heavily on whether research is performed using aggregate stock market indices, sectoral indices, or firm-level data—and whether stock markets operate in net oil-importing or net oil-exporting countries. Additionally, conclusions vary depending on whether studies use symmetric or asymmetric changes in the price of oil, or whether they focus on unexpected changes in oil prices. Finally, we find that most studies show oil price volatility transmits to stock market volatility, and that including measures of stock market performance improves forecasts of oil prices and oil price volatility.

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Executive Summary

Do oil prices and stock markets move in tandem? In opposite directions? The complex and time varying relationship between oil prices and stock markets has caught the attention of the financial press, investors, policymakers, researchers, and the general public in recent years. The Energy Information Administration (EIA) also has an interest in this relationship—EIA is responsible for analyses and modeling related to oil prices, including any factors that impact the oil price.

In light of such attention, this paper reviews research on the oil price/stock market rate relationship. We begin by reviewing theoretical transmission mechanisms between oil and stock market performance, highlighting five different channels: stock-valuation, monetary, output, fiscal, and uncertainty. The next two chapters look at the historical relationship between oil prices and stock market returns. We review and summarize key studies in this literature, differentiating between analysis at aggregate, sectoral, and firm levels; symmetric and asymmetric effects; oil-importing and oil-exporting countries; and time-varying impacts of one on the other.

We then turn to research that looks into the historical relationship between oil price volatility and stock market volatility. Here, we differentiate between studies based on static approaches—including those that separate out oil-importing and oil-exporting countries—and those focused on a possible time-varying relationship. Our next chapter moves from the historical relationship to forecasting, specifically using information from stock markets to forecast either oil prices or oil price volatility. The paper concludes with some implications and possibilities for future research.

The majority of papers we survey study the impacts of oil markets on stock markets—although research in the reverse direction does exist. In general, we find that the causal effects between oil and stock markets depend heavily on whether research is performed using aggregate stock market indices, sectoral indices, or firm-level data—and whether stock markets operate in net oil-importing or net oil-exporting countries. Yet there are some specific conclusions:

- The majority of empirical studies which use aggregate stock market indices suggest that positive oil price changes lead to negative stock market returns for oil-importing countries. Stock markets of oil-exporting economies tend to respond positively to oil price increases.
- In addition to the country, there appear to be heterogeneous responses to oil price changes depending on industrial sector: oil-users show a negative relationship, oil-related and oil-substitutes show a positive relationship. Firm-level data suggest that the impact of oil on stock returns depends on the size and sector of the firm.
- Recent work shows that the relationship between oil and stock markets is likely time-varying.
- Oil price volatility exercises a significant effect on stock market volatility. This does not hold true for the US market, as it is the only stock market volatility that exercises a significant effect on oil market volatility. These findings hold for both aggregate and sectoral indices.
- There are few studies that look into forecasting oil prices and oil price volatility using stock market information. Those that do find that including measures of stock market performance improves forecasts of oil prices and oil price volatility.

We also find that there are large gaps in current understanding of the oil price/stock market relationship. Theoretically, transmission channels by which stock markets affect oil prices should be developed. On the empirical side, future research should use aggregate or sectoral stock market indices that represent actual tradable financial assets, such as index futures contracts, ETFs of stock indices, etc. There is also scope to extend this line of research using firm-level data. Another interesting area for further study is investigation of possible time-varying tail dependence between oil prices and stock market indices, or tail dependence between different sectors.

Gaps in the literature on forecasting oil prices with stock market information are particularly acute. It is evident from the scarce literature in this line of research that significantly more research should be conducted on the benefit of using the information content of stock markets in forecasting both oil prices and oil price volatility. Another interesting avenue for further research is the production of density oil price and oil price volatility forecasts, based on information extracted from the stock market fluctuations.

1. Introduction

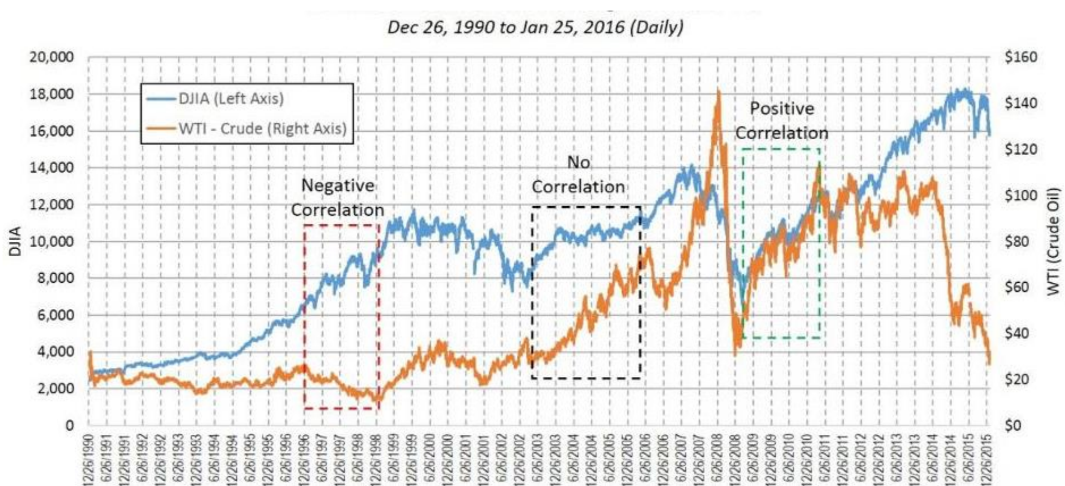
Oil price fluctuations over the last ten years have been remarkable. After an extremely calm twenty-year period between 1986 and 2006, prices between 2007 and 2009 rose from $60 to $145, and then fell sharply to $30. A few years later—in 2014 and 2015—oil prices lost nearly 75% of their value within a few months.

Such price surges, sharp declines and volatility have coincided more and more with corresponding moves in stock markets, attracting the attention of the research community, practitioners, policy makers, and investors in order to assess the interconnectedness between the two markets[1].

During important events related to the oil market—the price rally between 2006 and 2008, price fluctuations during the Arab Spring, or the oil price plunge of 2015—the relationship between oil and stock markets has caught the attention of media, particularly the financial press (see, for instance, "Oil slide spurs global equity rally" (Financial Times, 2006), "How the Syrian unrest affects world markets" (The Conversation, 2013), "Oil, Stocks at Tightest Correlation in 26 Years" (Wall Street Journal, 2016) or "Oil rally propels Wall Street to record" (Reuters, 2016)).

For all its fanfare, the oil/stock market relationship does not necessarily exhibit a stable pattern over time. Figure 1 shows there are periods of coupling and decoupling between the two markets.

Figure 1. Dow Jones industrial average and WTI crude oil prices



Source: Forbes, 2016.

Thus, there are some key questions that seek convincing responses. For instance, what explains the relationship between oil and stock prices? How stable is this relationship and what factors might drive structural shifts? Do all stocks respond similarly to oil prices changes? Are the links between oil and

[1] Such interest follows the well-established evidence that oil prices exercise a significant impact on economic activity. Hamilton (1983) pioneered this line of research, claiming that seven out of the eight US recessions from WWII until the early 1980's coincided with oil price surges. Hamilton (1983) also maintained that since 1973 the relationship between oil prices and economic conditions had become more systematic.

stock markets the same for oil-importing and oil-exporting economies? How important is financialization of the oil market for financial markets?

This report provides a detailed account of the current literature as it stands in relation to answering such questions. We also hope to open new avenues in this interesting line of research. We begin in Chapter 2 by reviewing the theoretical transmission mechanisms between oil and stock market performance. Chapter 3 focuses on the empirical relationship between oil price changes and stock market returns, whereas Chapter 4 concentrates its attention on the effects of oil price shocks on stock market returns. Chapter 5 discusses the interconnectedness between the volatilities of the two markets, and Chapter 6 analyses the role of stocks markets in forecasting oil prices and oil price volatility. Chapter 7 concludes the report.

2. Theoretical Transmission Mechanisms Between Oil and Stock Market Returns

In this chapter, we set the scene and explain some theoretical transmission mechanisms by which oil price changes can alter the behaviour of stock markets. We categorize the channels in five different ways.

2.1 Stock valuation channel

The stock valuation channel is the direct channel by which oil prices influence stock markets. Making this clear requires two equations: first, we define stock returns $(R_{i,t})$ as the first log-difference as in Eq. 1:

$$\boldsymbol{R_{i,t} = log\left({}^{P_{i,t}}\!/_{P_{i,t-1}}\right)}, \tag{1}$$

where $P_{i,t}$ denotes the stock price of firm i at time t. Second, economic theory suggests that current stock prices reflect the discounted future cash flows of a particular stock (Huang *et al.*, 1996). This can be shown as:

$$\boldsymbol{P_{i,t} = \sum_{n=t+1}^{N}\left(\frac{E(CF_n)}{\left(1+E(r)\right)^n}\right)}, \tag{2}$$

where CF_n is the cash flow at time n and r is the discount rate. $E(\cdot)$ denotes the expectation operator.

Eqs. 1 and 2 show that stock returns are impacted by factors that can alter the expected cash flows and/or the discount rate, including oil prices. Oil price changes can alter a firm's future cash flows either positively or negatively, depending on whether the firm is an oil-user (oil-consumer) or oil-producer (see Oberndorfer, 2009; Mohanty and Nandha, 2011). For an oil-consuming firm, oil is one of the major production factors and consequently an increase in oil prices will result in an increase of production costs (assuming that there are no perfect substitution effects between production factors, see Basher and Sadorsky, 2006), which, in turn, will reduce profit levels and thus future cash flows (Bohi 1991; Mork, Olsen, and Mysen 1994; Hampton, 1995; Brown and Yucel 1999; Filis *et al.*, 2011). On the other hand, for an oil-producer the oil price increase will result in increased profit margins and thus increased expected cash flows. Intuitively, we expect oil-users to exhibit bearish behaviour during periods of oil price increase, whereas the reverse holds true for oil-producing firms.

2.2 Monetary channel

Oil price changes also affect the expected discount rates of future cash flows (see Eq. 2). According to Mohanty and Nandha (2011), the discount rate is at least partially composed of expected inflation and expected real interest rates. Thus, the second transmission mechanism by which oil price changes impact stock returns is through inflation and interest rates.

As mentioned in Section 2.1, rising oil prices result in increased production costs. However, these costs will be transferred to consumers, leading to higher retail prices and thus higher expected inflation (see Abel and Bernanke 2001; Hamilton 1996, 1988; Barro 1984, among others). Assuming that a central bank follows some type of rule[2], we expect monetary policy makers to increase short-term interest rates in response to higher inflationary pressures (Basher and Sadorsky, 2006).

There are two main effects of the increased short-term interest rates on stock markets. First, increases in short-term interest rates lead to an increase in commercial borrowing rates (i.e., discount rates) for any future firm investments, raising the borrowing costs of firms. Furthermore, the increased borrowing costs lead to fewer positive net present value (NPV) projects (lower cash flows). Thus, either due to increased discount rates and/or lower cash flows, stock prices decrease in value.

We should highlight here that the magnitude of the aforementioned effects depends on the central bank's credibility to stabilize inflation. Assuming a highly credible central bank, we maintain that inflation expectations will remain stable, despite an oil price increase, and thus close to the inflation target. Through this expectations channel, we do not expect a significant increase in inflation following an oil price increase. By contrast, in the case of a low credibility central bank, inflation expectations will be volatile and this results in a larger change of inflation expectation, following an oil price increase, leading to an even worse impact on stock price levels.

2.3. Output channel

The third channel is the output channel. The literature maintains that oil price fluctuations affect aggregate output (see, *inter alia*, Hamilton, 1983; Hamilton, 2003; Kilian, 2008a, 2008b; Hamilton, 2009a). According to this channel, positive oil price changes are expected to have both an income and a production cost effect, which will lead to changes in aggregate output. The production cost effect was explained in Section 2.1, so we will concentrate on the income effect in this section.

More specifically, increased oil prices tend to lead to lower the discretionary income of households, due to the changes in retail prices (as a result of increased production costs), but also due to the increased prices of gasoline and heating oil (Bernanke, 2006; Edelstein and Kilian, 2009). Lower income leads to lower consumption and thus aggregate output, which further leads to lower labour demand. Put differently, an increase in oil prices will worsen the terms-of-trade for an oil-importing economy, which will result in lower income and a negative wealth effect on consumption, and in turn to lower aggregate demand (Svensson, 2005 and 2006). Stock markets tend to respond negatively to such developments. We maintain that this will be the response of stock markets, based on Eqs. 1 and 2. In particular, lower aggregate demand leads to lower expected cash flows for firms, which further leads to lower stock prices.

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[2]The most well-known rule is that of Taylor (Taylor, 1993). It is designed to approximate the response of short-tern nominal interest rates, as these are set by the central bank, when economic conditions change. The rule assumes that the monetary policy target is to stabilize the economy and price levels. More specifically, the rule "recommends" short-term nominal interest rates are influenced by the actual inflation rate, the inflation gap (i.e. the difference between the actual inflation rate and the inflation target), the output gap (i.e. the difference between the actual level of output and the output at "full employment" conditions) and expected equilibrium short-term interest rates that are consistent with a "full employment" condition. Thus, the rule suggests an increase in interest rates when inflation or output is above the target, for example.

These effects are not expected to hold for all economies. On the contrary, they depend on whether an economy is oil-importing or oil-exporting. The aforementioned sequence of events holds for an oil-importing economy. On the other hand, even though an oil-exporting economy will also experience negative production cost effects, it will benefit from a positive income effect, due to increased oil revenues (the value of export demand for oil rises), leading to higher aggregate demand and thus higher output. The positive change in the aggregate demand will occur only if the income effect is such that it can counterbalance the negative production cost effect. In such a case, stock markets will respond favourably to the increased output, as it will boost the expected cash flows of the firms that operate in the country.

2.4. Fiscal channel

The fiscal channel is primarily concerned with oil-exporting economies, which are financing physical and social infrastructure using their oil revenues (see, Ayadi 2005; Farzanegan 2011; Emami and Adibpour 2012). Increased oil prices tend to lead to a transfer of wealth from oil-importing economies to oil-exporting ones (Dohner, 1981), which allow for increased government purchases. Assuming that consumption and government purchases are considered complements, then the latter will lead to higher household consumption. In such a case, private firms are expected to increase their cash flows and thus their profitability. Such developments will push stock prices to higher levels and the stock market will exhibit a bullish period.

By contrast, if consumption and government purchases are regarded as substitutes then the opposite impact will be evident, due to the crowding out effects. Stock markets will respond negatively to such developments, as the substitution effect will drive out the most productive private capital of the economy.

2.5. Uncertainty channel

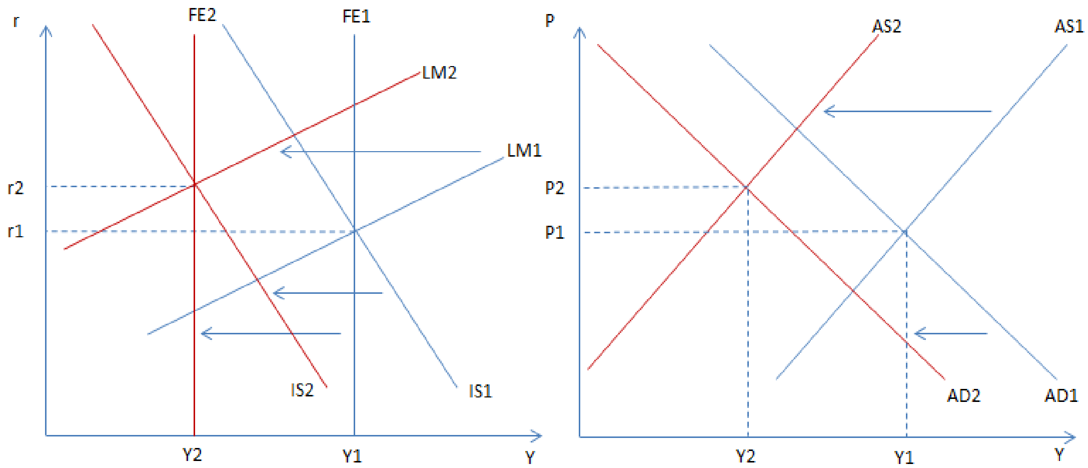
The final transmission channel is the uncertainty channel, suggested by Brown and Yücel (2002). In particular, rising oil prices cause higher uncertainty in the real economy, due to the effects of the former on inflation, output, consumption, etc. Thus, increased oil prices will reduce firms' demand for irreversible investments, which in turn, reduce expected cash flows. Furthermore, uncertainty is also propagated to households which reduce their consumption of durable goods (Bernanke 1983; Pindyck 2003). Rising uncertainty about future oil costs increases the incentives of households to save rather than consume (Edelstein and Kilian, 2009). It is worth noting here that as uncertainty rises due to increased oil prices, the value of postponing both investment and consumption decisions increases and thus, a decrease in the incentive to invest or consume is observed, which thereby dampens economic growth prospects (Chuku et al., 2010) and thus stock market returns.

2.6. Combining the different channels in an aggregate framework

Effects of the aforementioned channels are illustrated in Figures 2 and 3 using the IS-LM/AD-AS framework[3]. These are general representations chosen to highlight the five channels—specific quantitative values ultimately depend upon the shapes of each curve. Additionally, the magnitude and timing of any effects are not obvious and depend on the responsiveness of aggregate demand and output.

Figure 2 shows the effects of a positive oil price change in an oil-importing economy.

Figure 2. Rolling window correlation between oil price and major US dollar index



Adapted from Filis and Chatziantoniou (2014). Y1, P1, AD1, AS1, FE1, LM1, IS1, r1 refer to aggregate output, price levels, aggregate demand, aggregate supply, labour market, money market equilibrium, goods market equilibrium and interest rates, respectively, before the oil price increase. Y2, P2, AD2, AS2, FE2, LM2, IS2, r2 refer to aggregate output, price levels, aggregate demand, aggregate supply, labour market, money market equilibrium, good market equilibrium, and interest rates, respectively, after the oil price increase.

We identify four major issues that need to be addressed in order to classify the oil price/exchange rate relationship. The first is to disentangle a backward ("in-sample") and a forward looking ("out-of-sample") analysis. The term in-sample corresponds to a backward perspective by considering the full history of available data to explain past characteristics of the relationship between oil prices and exchange rates. The out-of-sample perspective focuses on predictability, by studying whether oil price forecasts in a given year, for example, can be improved by taking US dollar exchange rates into account. Figure 3 illustrates the difference between in-sample and out-of-sample evidence. As will be discussed later, the frequent finding that exchange rates and oil prices move together over the long-run does not necessarily imply that one is useful when forecasting the other.

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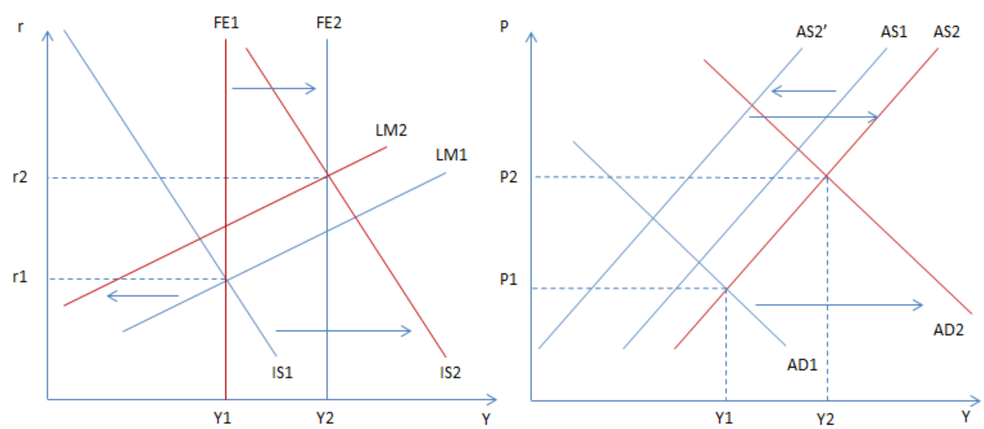
[3] IS-LM corresponds to "Investment-Savings" and "Liquidity-Money"; AD-AS refers to "Aggregate Demand" and "Aggregate Supply". The IS curve represents equilibrium in the goods markets, the LM curve equilibrium in the money market. The goods market is in equilibrium when investments equal savings. The money market is in equilibrium when money supply equals money demand. A general equilibrium is achieved when money and goods markets are in simultaneous equilibrium.

A higher oil price leads to lower disposable—due to increased heating and fuel costs—and this negative income effect pushes the AD curve to the left (from AD1 to AD2). The AD curve shifts further to the left due to production effects, as some portion of these will be passed on to consumers via increased retail prices, lowering consumption. The AS curve also responds to the negative income effect and increased production costs, shifting left (from AS1 to AS2). These leftward shifts of the AD and AS curves leads to cost-push inflation (price levels move from P1 and P2) and lower output (from Y1 to Y2). Lower consumption and output also lead to reduced levels of employment (the labour market curve moves from FE1 to FE2).

Assuming that the monetary authority tries to counteract potential increases in inflation by reducing the supply of money (the LM curve moves from LM1 to LM2), short-run interest rates will be higher (from r1 to r2). Additionally, the effects of the oil price increase on inflation, output, consumption, etc., lead to an increase in economic uncertainty. The latter forces firms to reduce their investment activity, which can be depicted by the leftward shift of the IS curve from IS1 to IS2. Taken together, these movements lead to lower stock market performance.

Figure 3 shows the effects of a positive oil price change in an oil-exporting economy.

Figure 3. The effects of an oil price increase on an oil-exporting country



Adapted from Filis and Chatziantoniou (2014). Y1, P1, AD1, AS1, FE1, LM1, IS1, r1 refer to aggregate output, price levels, aggregate demand, aggregate supply, labour market, money market equilibrium, goods market equilibrium and interest rates, respectively, before the oil price increase. Y2, P2, AD2, AS2, FE2, LM2, IS2, r2 refer to aggregate output, price levels, aggregate demand, aggregate supply, labour market, money market equilibrium, good market equilibrium, and interest rates, respectively, after the oil price increase.

Two opposing forces exist for an oil-exporting economy in the case of an oil price increase. On the one hand, increased oil prices lead to higher production costs (production cost effect), leading the AS curve to shift to the left (from AS1 to AS2'). On the other hand, higher oil prices lead to higher disposable income and faster economic growth (income effect), and both the AD and AS curves shift to the right (to AD2 and AS2, respectively). The income effect is generally larger than the production effect in oil exporting economies, and thus the aggregate output level increases from Y1 to Y2. This also leads to positive changes in the demand for labor (FE moves from FE1 to FE2).

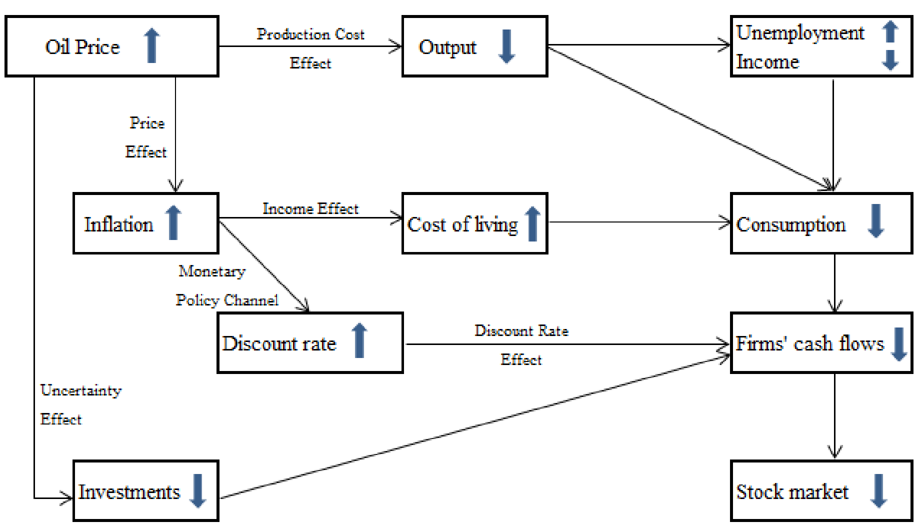
Shifts of the AD and AS curves, however, trigger demand-pull inflation (price levels move from P1 to P2). Assuming that the monetary authority of the oil-exporting economy responds with contractionary monetary policy, this shifts the LM curve to the left (from LM1 to LM2), creating upward movement in interest rates (from r1 to r2).

There are two more effects that a positive oil price increase causes in an oil-exporting economy: the possibility for higher government purchases and lower economic uncertainty. Both these effects tend to push the IS curve to the right (from IS1 to IS2). Taken together, these movements lead to higher stock market performance.

2.7. Conclusion

Overall, we show that there are five channels by which oil price fluctuations can exercise an impact on stock market returns. It is evident from Chapter 2 that the various channels can either impact firms' cash flows or their discount rate. In both cases the transmission channels suggest that higher oil prices lead to lower stock market returns. We should highlight though, that these effects hold true for stock markets operating in oil-importing economies. By contrast, in oil-exporting countries the effects of higher oil prices are expected to be positive for stock market returns. A summary of the aforementioned channels is shown in Figure 4.

Figure 4. Transmission channel of positive oil price changes



Adapted from Tang et al. (2010).

A possible area for further study in the theoretical transmission channels of the oil price effects would be to show that these might be asymmetric in terms of positive and negative oil price changes. Even more, theoretical transmission channels by which stock markets affect oil prices should be also developed.

3. Relationship Between Oil Price and Stock Market Returns

This chapter is concerned with in-depth analysis of the relationship between oil price changes and stock market returns. We investigate the empirical evidence and review the econometric methods and data used in the literature. We conclude by providing ideas for future research.

3.1. Empirical evidence

3.1.1. Aggregate, sectoral and firm level analysis

Hamilton (1983) was among the first to document that oil price changes regularly exercise a significant impact on economic activity in the US. Hamilton (1983) went as far as to suggest that most US recessions from the end of WWII up until 1983 were the result of energy price surges.

Interestingly enough, despite this early evidence of the effects of oil prices on economic activity, the research on the effects of oil prices on stock markets took about a decade to begin in earnest. In particular, the earliest studies in this strand of the literature are these by Brown and Otsuki (1990), Ferson and Harvey (1995) and Kaneko and Lee (1995), who examine the effects of oil, among other determinants, on stock market returns and report negative effects[4]. Nevertheless, it is the seminal papers by Jones and Kaul (1996) and Huang *et al*. (1996) that led to increased interest in the relationship between oil and stock market returns. Jones and Kaul (1996) report that oil exerts a significantly negative impact on aggregate stock market returns, whereas Huang *et al*. (1996) do not offer support to these findings, claiming that the effects of oil on stock markets are non-existent.

Since then, a wealth of literature has emerged investigating the potential impact of oil price changes on aggregate stock market indices. See, for instance, Filis and Chatziantoniou (2014), Asteriou and Bashmakova (2013), Ciner (2013), Lee and Chiou (2011), Laopodis (2011), Filis (2010), Chen (2010), Miller and Ratti (2009), Driesprong *et al*. (2008), Nandha and Faff (2008), O'Neill *et al*. (2008), Park and Ratti (2008), Bachmeier (2008), Basher and Sadorsky (2006), Hammoudeh and Li (2005), Hammoudeh and Aleisa (2004), Sadorsky (2001), Papapetrou (2001), Faff and Brailsford (1999), Sadorsky (1999), among others.

The picture painted from the aforementioned studies suggests that positive oil price changes lead to negative stock market returns. For instance, Sadorsky (1999) focuses on US market and reports that positive changes in the price of oil are associated with decreased stock market returns, whereas the reverse does not hold. Even more, his findings provide evidence that the effects of oil on stock markets became more important between 1986 and 1996—a period that saw significant oil price declines. Papapetrou (2001) reports similar findings, although the focus is on the emerging stock market of Greece. More recently, Asteriou and Bashmakova (2013) focus on emerging stock markets and find that stock market returns in the Central and Eastern European Countries (CEEC) economies respond negatively to positive innovations of oil prices.

On the other hand, there are authors who maintain that oil price changes do not impact stock returns (see, *inter alia*, Al Janabi *et al*., 2010; Jammazi and Aloui, 2010; Apergis and Miller, 2009; Cong *et al*.,

[4] The studies of Chen *et al*. (1986) and Hamao (1988) show that oil does not exhibit any effect on stock market returns.

2008; Henriques and Sadorsky, 2008). For instance, Cong *et al*. (2008) investigate the effects of oil prices changes on Chinese stock market returns and find that the former does not provide any predictive information on stock market returns in China. Jammazi and Aloui (2010) support the findings of Cong at al. (2008), examining the oil-stock relationship for UK, France and Japan.

All the aforementioned studies focus their attention on aggregate stock market indices when examining the oil-stock relationship. Nevertheless, the use of aggregate stock market indices may mask heterogeneous responses from different industrial sectors due to their different characteristics. These characteristics are related to whether industrial sectors can be classified as oil-users, oil-substitutes or non-oil-related.

The evidence provided by the empirical literature is that there are indeed heterogeneous responses to oil price changes by different industrial sectors (see, among others, Broadstock *et al*., 2014; Scholtens and Yurtsever, 2012; Arouri, 2012; Broadstock *et al*., 2012; Ramos and Veiga, 2011; Arouri, 2011; Elyasiani *et al*., 2011; Mohanty *et al*., 2011; Narayan and Sharma, 2011; Arouri *et al*., 2011a; Arouri and Nguyen, 2010; Nandha and Faff, 2008; Boyer and Filion, 2007; El-Sharif *et al*., 2005; Hammoudeh and Li, 2005; Hammoudeh *et al*., 2004).

These studies provide strong evidence that the Oil & Gas sector responds positively to oil price increases. For instance, Nandha and Faff (2008), who analyze 35 Datastream® global industry indices, report that positive oil price changes have a positive effect on the Mining and Oil & Gas industries. Nevertheless, El-Sharif et al. (2005) opine that this response is rather weak in the UK Oil & Gas sector.

By contrast, authors such as Narayan and Sharma (2011) find evidence that sectors such as Supply, Manufacturing, Food, Chemical, Medical, Computer, Transportation, Real Estate and General Services respond negatively to positive oil price changes, whereas inconclusive findings are reported for the Electricity, Engineering and Financial sectors. Similarly, Hammoudeh and Li (2005) report the negative effects of oil price changes in the case of the Transportation sector. These findings are also supported by Nandha and Brooks (2009).

Along a similar vein, Elyasiani et al. (2011) show that positive oil price changes exercise a positive and direct effect on US oil-related and oil-substitute sectors (such as Coal, Electric-Gas Services, Oil & Gas Extraction and Oil Refineries), whereas the effect is negative and indirect for oil-using sectors (such as Buildings, Chemicals, Plastic & Rubber, Metal, Industrial Machinery, Transport Equipment and Air Transportation) and financial industries.

Concerning European stock markets, Scholtens and Yurtsever (2012) provide similar evidence. More specifically, they suggest that the impact of oil prices changes is heterogeneous for the different sectors. The authors consider 38 industrial sectors from 15 European countries and show that almost all sectors respond negatively to positive oil price changes, apart from the Oil & Gas and Mining sectors, which respond positively to oil price changes.

Arouri and Nguyen (2010) support these findings considering data from 12 pan-European industrial sectors. In particular, they report a negative effect for sectors such as Food and Beverages, Health Care and Technology and a positive effect on the Financial, Oil & Gas, Industrials, Basic Materials and Personal and Household Goods sectors. It is interesting to note though that Arouri (2011) in a subsequent study reports that only the Oil & Gas sector exhibits a positive response to positive oil price changes, whereas a negative effect is evident for the Financials and Consumer Goods sectors.

Summarizing the evidence from the industrial sectors, we maintain that oil-related and oil-substitute sectors are positively affected by changes in oil prices, whereas the reverse holds for oil-user and non-oil-related (or financial) sectors.

Interestingly enough, the literature has not extensively focused on the effects of oil price changes on firm-level stock returns, which would allow for an even more in-depth analysis, given that firms within the same sector may well exhibit heterogeneous responses to oil price changes. Boyer and Filion (2007) is one of the early studies in this line of research. They focus on 105 Canadian oil and gas firms and report that firms' stock returns respond positively to raising oil prices, mainly due to the oil-exporting character of Canada. Sadorsky (2008) uses data from 1483 firms of the S&P1500 index and maintains that firm-level stock returns decline when oil prices increase, although these effects are more important for medium-sized firms, contrary to the small and large companies.

Narayan and Sharma (2011) also focus on US firm-level data. In particular, they consider 560 listed firms from 14 different sectors of the New York Stock Exchange. Their findings lend support to the previously reported evidence, i.e. that firms' response to oil price changes is heterogeneous and depends on the sector and the size of the firm. Similarly, Mohanty et al. (2013), concentrates on 54 US oil and gas companies and reach the same conclusion as Narayan and Sharma (2011).

Phan *et al*. (2015), on the other hand, separate their sample into oil producing and oil consuming firms. More specifically, they use data from the top-20 listed firms from 5 different US sectors (construction, air transport, truck transport, chemical manufacturing and petroleum). They conclude that increased oil price changes lead to appreciation of oil producer stock prices, whereas the reverse holds true for oil consumers. Additionally, Tsai (2015) uses daily data from 682 US listed firms and reports that the effects of oil prices on stock returns has changed as a result of the Global Financial Crisis (GFC) of 2007-09. More specifically, Tsai (2015) finds that before the GFC, oil prices were negatively influencing firms' stock returns. However, since the GFC the effects have become positive. Finally, Tsai (2015) suggests that these effects are size specific, similar to Narayan and Sharma (2011).

3.1.2. Symmetric and asymmetric effects

The financial literature also tries to identify whether oil prices exercise asymmetric effects on stock market returns (see, *inter alia*, Jiménez-Rodríguez, 2015; Broadstock *et al*., 2014; Chen, 2010; Cong *et al*., 2008; Park and Ratti, 2008)[5]. It is worth noting that these studies focus on either aggregate or sectoral stock market returns.

[5] The majority of the studies that concentrate on the asymmetric effects of oil prices focus on macroeconomic variables rather than financial variables (see, *inter alia*, Herrera *et al*., 2015; Kilian and Vigfusson, 2011; Jiménez-Rodríguez and Sánchez, 2005; Cunado and Gracia, 2005; Hamilton, 2003, 1996).

There are three types of asymmetric specifications that these studies are exploring, namely positive and negative oil price returns, scaled oil price increases and decreases (*SOPI* and *SOPD*) and net oil price increases (*NOPI*)[6].

Park and Ratti (2008) uses all three asymmetric specifications and conclude that while the US stock market responds heterogeneously to positive and negative oil price changes, such evidence is not apparent for European stock markets. Recently, Broadstock et al. (2014) concentrate on positive oil price changes (R_{op}^{+}) and $NOPI_t$. Their findings suggest that there is indeed an asymmetric effect of oil prices, given that some markets exhibit greater responses to positive changes in oil prices (e.g. Tokyo, Korea and Taiwan). Nevertheless, they maintain that different specifications for capturing the asymmetric effects of oil prices could yield different results and, thus, authors should be very careful when choosing the asymmetric specification.

Furthermore, Jiménez-Rodríguez (2015) considers the $SOPI_t$, $SOPD_t$ and $NOPI_t$ specifications and reports that oil price increases tend to trigger negative responses in stock markets, which are of a higher magnitude compared to the positive responses of the latter when oil prices decrease. Phan *et al*. (2015) also confirm the asymmetric effects of oil prices for firm-level stock return data, given the heterogeneous responses of stock price returns to positive and negative oil price changes. Further evidence in favor of asymmetric effects is provided in Tsai's (2015) study, although only after the GFC period. More specifically, the results indicate that before the GFC there was no evidence of asymmetric

[6] The simplest specification is defined as:

$$\begin{aligned} \boldsymbol{R_{op}^{+}} &= \boldsymbol{max\left(0, R_{op} > 0\right)} \\ \boldsymbol{R_{op}^{-}} &= \boldsymbol{min\left(R_{op} < 0, 0\right)}, \end{aligned} \tag{1}$$

where R_{op} denotes log oil price returns, which are differentiated as either positive or negative.

The second most common specification concerns scaled oil price increases and decreases ($SOPI_t$ and $SOPD_t$, respectively), which try to capture the effects of oil price changes (either positive or negative) after a long period of stability (Lee et al., 1995). For monthly data, the $SOPI_t$ and $SOPD_t$ are estimated based on a AR(12)-GARCH(1,1) model, as follows:

$$\begin{gathered} \boldsymbol{R_{op,t} = b_0 + b_1 R_{op,t-1} + b_2 R_{op,t-2} + \cdots + b_{12} R_{op,t-12} + e_t}, \\ \boldsymbol{e_t | \Omega_{t-1} \sim N(0, \sigma_t^2)}, \\ \boldsymbol{\sigma_t^2 = \gamma_0 + \gamma_1 e_{t-1}^2 + \gamma_2 \sigma_{t-1}^2}, \\ \boldsymbol{SOPI_t \;= max\left(0, \hat{e}_t \big/ \sqrt{\hat{\sigma}_t^2}\right)}, \\ \boldsymbol{SOPD_t \;= min\left(-\hat{e}_t \big/ \sqrt{\hat{\sigma}_t^2}, 0\right)}, \end{gathered} \tag{2}$$

where $\hat{e}_t$ is the error term and $\hat{\sigma}_t^2$ is the conditional variance based on the information set Ω_{t-1}.
Finally, the third specification was developed by Hamilton (1996), who focuses on the net oil price increase ($NOPI_t$), to identify whether the log oil price at month t (op_t) is higher compared to oil prices of the past year, such that:

$$\boldsymbol{NOPI_t = max(0, op_t - max\{op_{t-1}, op_{t-2}, op_{t-3}, \dots, op_{t-12}\})}. \tag{3}$$

effects. By contrast, during and after the GFC, firm-level stock returns are more reactive to negative changes in oil prices. Finally, Narayan and Gupta (2015) suggest that there is evidence of asymmetric oil price effects, given that negative changes in oil prices allow for superior prediction of stock price returns, compared to positive changes.

Nevertheless, there are studies which do not offer support to the aforementioned findings, concluding that there are no asymmetric effects of oil prices on stock returns (see, for instance, Bachmeier, 2008; Nandha and Faff, 2008).

3.1.3. Oil-importing countries and oil-exporting countries

The aforementioned effects of oil price changes on stock markets returns do not necessarily hold for all countries. Rather, Mohanty *et al*. (2011) maintains that oil price effects are different in countries that are oil-exporters, compared to these that are oil-importers. Hence, the negative relationship that was established in the previous sections does not necessarily hold for stock markets operating in oil-exporting countries.

Authors such as Wang *et al*. (2013), Arouri and Rault (2012), Mendoza and Vera (2010), Korhonen and Ledyaeva (2010), Bjornland (2009), Lescaroux and Mignon (2008), Park and Ratti (2008) and Bashar (2006) offer support to the hypothesis that the stock markets of oil-exporting economies tend to respond positively to oil price increases. The theoretical underpinning of this hypothesis stems for the arguments presented in Section 2.3 of this report.

By contrast, Al Janabi et al. (2010) report that oil prices do not tend to affect the stock markets of the Gulf Corporation Council countries (GCC). Thus oil prices cannot be used as predictors for GCC stock markets.

3.1.4. Time-varying relationship

A recent strand in this line of research acknowledges the fact that the relationship between oil and stock markets may not be stable over time. On the contrary, a time-varying relationship may prevail. Miller and Ratti (2009) are among the first to employ a quasi-time-varying framework in order to examine the relationship between oil price movements and stock market performance for the period from 1971 to 2008. More specifically, the authors claim that a negative relationship holds during the 1970s and the 1990s. By contrast, in the 1980s the authors cannot report any significant effects of oil prices on stock returns. Finally, they find evidence that the negative effects of oil prices on stock markets are reversed into positive effects after 1999.

The time-varying relationship between oil and stock markets is examined more formally, using multivariate GARCH models, by Awartani and Maghyereh (2013), Degiannakis et al. (2013), Antonakakis and Filis (2013), Chang et al. (2013), Broadstock et al. (2012), Sadorsky (2012), Filis et al. (2011), Choi and Hammoudeh (2010), and Bharn and Nikolova (2010) among others. These studies corroborate that the relationship between oil prices and stock market is time-varying and mainly driven by economic or geopolitical developments. Thus, there are periods when the two markets exhibit a positive relationship, whereas in other periods a negative relationship prevails.

For instance Filis et al. (2011) focus on both oil importing and oil exporting countries, and show that during geopolitical events (i.e. unrest in the Middle East) the relationship between oil price changes and stock returns is negative, whereas during recessions or economic booms the relationship turns positive. Even more, the authors do not find any significant relationships between oil exporting and oil importing stock markets. Similarly, Broadstock et al. (2012) concentrate on China and report a sharp increase in the correlation between oil and stock returns since the GFC. A different approach is undertaken by Antonakakis and Filis (2013), who examine the time-varying effects of oil prices changes on the dynamic correlation between stock markets. They show that oil price changes affect the time-varying stock market correlations among oil-importing countries, whereas no effects are reported for the correlations among oil-exporting countries.

Furthermore, Degiannakis et al. (2013) confirm the aforementioned time-varying relationship for all industrial sectors, regardless of whether these are oil-users, oil-related, oil-substitutes and non-oil-related. Sadorsky (2012) focuses only on the technology and energy sector. He reports that the time-varying correlation between these two sectors and oil price changes fluctuates in both positive and negative regions for both sectors. This is a rather important finding given that the studies reviewed in Section 3.1.1 advocate in favour of a positive effect of oil price changes on the energy sector.

Finally, Awartani and Maghyereh (2013) show that the effects between oil and stock markets are time-varying and bidirectional. However, it is evident that the oil market exercises greater effects on stock markets rather than the reverse. In addition, they show that these bidirectional effects are more prominent after the GFC of 2007-09.

3.2. Econometric methods and data used

In terms of econometric methods and data, these vary depending on whether the authors consider aggregate and sectoral stock market indices or firm-level data. Furthermore, the choice of econometric framework depends on the hypothesis that is examined.

More specifically, authors who concentrate on aggregate and sectoral stock market indices are primarily using monthly data and Vector Autoregressive (VAR) models, where apart from the oil price changes and stock returns, they also consider other macroeconomic variables, such as industrial production, interest rates, unemployment, etc. (see, for instance, Filis and Chatziantoniou, 2014; Scholtens and Yurtsever, 2012; Park and Ratti, 2008; Papapetrou, 2001; Sadorsky, 1999). The second most common model that is employed for the identification of oil price effects on stock market performance is a GARCH (1,1) (see, inter alia, Broadstock *et al*., 2014; Elyasiani *et al*., 2011; Arouri and Nguyen, 2010).

By contrast, authors who consider firm-level data primarily use daily data. In these studies the most common approaches are the Capital Asset Pricing Model (CAPM) or the Fama and French (1993) 3-factor model, which are augmented to incorporate oil price changes (see, Phan et al., 2015; Mohanty *et al*., 2013; Narayan and Sharma, 2011, among other).

The use of real and nominal oil and stock market data vary among the different authors. In any case, we do not find heterogeneous results depending on the use of real or nominal data. This also applies for studies which examine either the asymmetric effects of oil prices or the effects of oil prices for oil-exporting and oil-importing economies.

On the other hand, studies that investigate the time-varying relationship between oil and stock markets (either for aggregate stock market or sectoral indices) use monthly data and employ multivariate GARCH models, such as the Dynamic Conditional Correlation by Engle (2002) or the BEKK model of Baba, Engle, Kraft and Kroner (1991) and Engle and Kroner (1995) (see, for example, Degiannakis *et al.*, 2013; Broadstock *et al*., 2012; Filis *et al.*, 2011; Choi and Hammoudeh, 2010)

3.3. Areas in need of future research

A summary of the key and most recent aforementioned studies can be found in Table A.1 in the Appendix.

An area of research that has recently attracted the attention of researchers in this strand of the literature is the examination of oil price effects on stock returns over various quantiles (see, Zhu *et al*., 2016a,b; Ding *et al*., 2016; Reboredo and Ugolini, 2016; Sukcharoen *et al*., 2014). In short, the studies seem to reach to a consensus that the dependence between oil and stock markets is mainly found either in the lower tail of the distribution or in both the lower and higher tails. This is an interesting and important area for further study given that future studies could investigate time-varying tail dependence, or tail dependence between different stock market sectors.

Another area for further research is the investigation of the indirect effects of oil prices on stock market returns. Broadstock *et al*. (2014) provide some early evidence that the effects of oil prices on firm-level stock market returns stem from the effects of oil on the market risk premium.

Finally, recently studies investigate the effectiveness of hedging strategies for a portfolio comprising oil prices and stock market indices (see, for instance, Arouri *et al*., 2011a; Arouri *et al*., 2012; Sadorsky, 2012). These studies maintain that a dynamic hedging strategy and dynamic portfolio rebalancing is required to constantly achieve a minimum-variance portfolio, given the time-varying relationship between oil and stock markets. Nevertheless, these studies use aggregate or sectoral stock market indices, which are not directly tradable[7]. Even more, additional evidence needs to be accumulated on whether these findings hold at a firm-level, and whether the reverse hedging opportunities still apply (i.e. whether stock markets function as a hedging tool for oil price fluctuations). Finally, future studies should expand on the applicability of the literature's results for investment purposes by focusing on optimal weight allocation for multi-asset portfolios (rather than the typical two-asset portfolio exercise), as well as on actual tradable financial assets, such as index futures, ETFs of stock indices, etc.

[7] For instance, an investor cannot trade the S&P500 index. Rather she can trade either an ETF that mirrors the S&P500 index's performance or an index futures contract on the S&P500 index.

4. Relationship Between Oil Price Shocks and Stock Market Returns

Having examined the relationship between oil price changes and stock markets, we proceed with the investigation of oil price shocks and stock market performance. The chapter starts with the definitions of oil price shocks and continues with an in-depth review of empirical findings. It then proceeds with the review of econometric methods and data employed in the financial literature. The chapter concludes with ideas for future research. The studies reviewed in this chapter focus on the real oil prices and real stock market returns.

4.1. Defining oil price shocks

The studies that have been reviewed in this report so far have used changes in oil prices, measured by the first log-difference, when assessing the oil-stock market relationship. However, identifying the sources that cause oil prices to change is also important in better understanding the relationship between oil and stock market performance. Thus, before we investigate this aforementioned relationship, we must first define an oil price shock. In short, an oil price shock reflects a change in the price of oil due to an unanticipated change in oil market fundamentals (i.e. global supply or demand of oil).

Hamilton (2009a, 2009b) maintains that oil prices change in response to either geopolitical or economic events, which suggests that oil prices change due to supply disruptions (*supply-side* shocks) or economic growth/downturns (*demand-side* shocks).

In particular, *supply-side* shocks are driven by events such as the Yom Kippur War in 1973, the Iranian revolution in 1978, Iraq's invasion of Iran and Kuwait in 1980 and 1990, respectively, the Arab Spring in 2010 or Syrian unrest in 2011. Such shocks lead to major oil production disruptions, which are not accommodated by a similar reduction in the demand for oil and thus drive oil prices to higher levels.

Similarly, demand-side shocks are related to oil price changes which are influenced by movements in the global business cycle. For instance, the remarkable growth of the Chinese and other emerging economies from 2004 to 2007 significantly increased oil demand from these countries, while oil supply did not follow suit, driving oil prices to unprecedented levels. Equivalently, the global economic recession during the Global Financial Crisis of 2007-09 led to the collapse of oil prices, as the dramatic reduction of oil demand was not accompanied by a reduction in the supply of oil.

Kilian (2009) maintains that there are three types of oil price shocks (rather than two), namely, the *supply-side, aggregate demand*, and *precautionary demand* shocks. Kilian's *aggregate demand* shocks are the same as Hamilton's *demand-side* shocks.

However, according to Kilian (2009) geopolitical unrest, primarily observed in the Middle East region, does not lead to *supply-side* oil price shocks, as suggested by Hamilton (2009a, 2009b). On the contrary, Kilian argues that these events trigger *precautionary demand* shocks, which result due to the uncertainty that the geopolitical turbulence imposes on economic agents about the future availability of oil. To put it simply, Kilian maintains that economic agents expect a shortage in oil supply soon after initiation of geopolitical unrest and, thus, they increase their demand for oil instantly, driving oil prices to higher levels. Finally, he suggests that supply-side shocks are related to restrictions in oil supply by OPEC, via cartel behavior, as a strategy to inflate oil prices.

4.2. Empirical evidence

4.2.1. Aggregate, sectoral and firm level analysis

Kilian and Park (2009) utilize Kilian's (2009) definitions of oil price shocks for the US stock market, and show that the different oil price shocks trigger different responses from the stock market. In particular, they find that stock market returns do not really respond to *supply-side* shocks, whereas positive (negative) responses are observed during *aggregate demand* (*precautionary demand*) shocks. In other words, stock markets do not seem to react to OPEC decisions to restrict oil supply in order to generate increases in the price of oil. Such findings might be justified by the fact that OPEC decisions are somewhat anticipated and, thus, they are discounted by market participants. By contrast, positive aggregate demand shocks seem to be regarded as positive news for stock markets (hence the positive response), even though they create an upward movement in oil prices. This is expected, as positive *aggregate demand* shocks reflect periods of economic growth, which are positive news for financial markets. Finally, the negative responses of the stock markets to positive precautionary demand shocks suggest that uncertainty in the oil market, which is created due to geopolitical unrest and associated anticipated future shortfalls in oil supply, is transmitted to financial markets.

Kilian and Park (2009) also provide evidence that the effects of oil price shocks are industry specific. In particular, they show that the Automobile & Trucks and Retail industries only respond (negatively) to *precautionary demand* shocks, whereas Petroleum & Natural Gas and Precious Metals only respond (positively) to *aggregate demand* shocks.

Since Kilian and Park (2009), an increasing number of studies have examined the effects of the different oil price shocks on stock market returns and volatility (see, *inter alia*, Kang *et al*., 2017; Angelidis *et al*., 2015; Kang *et al*. 2015a; Fung and You, 2014; Gupta and Modise, 2013; Antonakakis et al., 2013; Abhyankar *et al*., 2013; Degiannakis *et al*., 2014; Kang and Ratti, 2013; Baumeister and Peersman, 2013; Basher *et al*., 2012).

For instance, Basher *et al*. (2012) use the MSCI emerging stock market index as a proxy of emerging stock market performance. They find that emerging stock markets do not seem to react to supply-side shocks, whereas a positive response is observed for both *aggregate demand* and *precautionary demand* shocks. The latter observation deviates from Kilian and Park (2009), who maintain that the precautionary demand shocks lead to lower stock market returns, given the uncertainty that they are associated with. However, a plausible explanation of this contradictory finding is the fact that the MSCI emerging stock market index comprises both oil-importing and oil-exporting economies (as we will explain in Section 4.2.2, the oil price shocks effects could be different for the two types of countries).

Another plausible explanation could be the fact that both India and China are included in the index. These two countries are heavy oil importers, which demand large oil quantities, regardless of its price, in order to sustain economic activity. Hence, their stock markets might be more resilient to increases in oil prices even if these are taking place due to geopolitical uncertainty.

Along a similar vein, Gupta and Modise (2013) concentrate on South Africa and their findings support those of Kilian and Park (2009) as far as the *aggregate demand* and *precautionary demand* shocks are concerned. However, they also find that negative *supply-side* shocks exercise a negative impact on stock market returns, suggesting that for South Africa restrictions in the supply of oil are not fully anticipated by the market. In addition, Abhyankar *et al.* (2013), focusing on the Japanese stock market, offer support to Kilian's and Park (2009) findings.

Angelidis *et al.* (2015) adopt a slightly different approach compared to the rest of the literature. In particular, they use Kilian's (2009) framework to extract the three oil price shocks and then they examine whether these shocks provide predictive information on stock market regimes (i.e. low and high risk periods) for the US market. The authors focus on both US stock market returns and volatility and their findings reveal that, indeed, disentangling oil price changes according to the individual shocks provides significantly incremental predictive information for the regime of US stock returns and volatility. In particular, they show that positive *supply-side* and *aggregate demand* shocks push the US market into bull territory (i.e. positive returns), whereas the *precautionary demand* shocks do not seem to matter. Interestingly, they document that the *precautionary demand* shock leads to the high volatility regime, whereas the *supply-side* and *aggregate demand* shocks do not exercise any significant effect. This is an interesting finding which suggests that stock returns and volatility respond differently to the different oil price shocks.

Kang *et al.* (2015a) chose to focus on the effects of oil price shocks on the covariates of US stock market returns and volatility. Their findings show that *supply-side* shocks do not exercise any effects, whereas negative responses are observed for the two demand-side shocks. In particular, positive *aggregate demand* and *precautionary demand* shocks lead to lower covariability between the returns and volatility of the US market.

Finally, Kang *et al.* (2017) investigate the effects of oil price shocks on both US aggregate oil and gas stock returns and for select oil and gas companies (i.e., Royal Dutch Shell, Exxon Mobil, BP and Chevron Corporation). Their findings for the aggregate industry's returns corroborate those of the previous studies. Additionally, they also show that even negative *supply-side* shocks trigger negative responses from the oil and gas sector's returns. Concerning the individual oil and gas companies, we notice that the effects are not company specific but they are industry-specific, as all shocks trigger positive responses from firm-level stock returns of the chosen oil and gas companies. The authors extend their findings in order to consider the effects of oil shocks on the upstream, midstream and downstream oil and gas companies, using one representative firm from each sector (ConocoPhillips, TransCanada Corporation and Valero Energy Corporation, respectively). They find that even though the responses of the latter firms are similar to the major oil and gas companies explained previously for the two demand-side shocks, ConocoPhillips, TransCanada Corporation and Valero Energy Corporation also react (negatively) to negative *supply-side* shocks.

Finally, there are studies that investigate the effects of the three oil price shocks on stock market volatility. Degiannakis *et al.* (2014), who focus on the European stock market, show evidence that stock market volatility responds negatively (i.e. reduces) to positive *aggregate demand* shocks, whereas no significant response is evident to *supply-side* and *precautionary demand* shocks. Their findings hold true for aggregate stock market indices, as well as for ten industrial sectors.

Kang *et al.* (2015a), on the other hand, concentrate on the US market and find that both demand-side shocks (i.e. *aggregate demand* and *precautionary demand* shocks) lead to lower stock market volatility.

4.2.2. Oil-importing countries and oil-exporting countries

Turning to studies that focus on oil-importing and oil-exporting stock markets, Apergis and Miller (2009) assess the impact of Kilian's (2009) oil price shocks on eight stock markets around the world (i.e. Australia, Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States). The authors report similar findings with Kilian and Park (2009), nevertheless, they maintain that these effects are small in magnitude and, thus, they conclude that international financial markets do not really value oil shocks.

On the other hand, Jung and Park (2011) focus on Norway and Korea and document the heterogeneous responses of stock market returns and volatility to the different oil price shocks. In particular, they report that *supply-side* oil price shocks are not valued by stock markets, since the former does not seem to exercise any effects on the latter. Nevertheless, they report heterogeneous responses to the two demand side shocks (i.e. *aggregate demand* and *precautionary demand* shocks), which stem from the fact that Norway is an oil exporter, whereas Korea is an oil-importing country. In particular, even though they find that the *aggregate demand* shocks exercise a positive effect on both the Norwegian and Korean stock markets, the effects are more prevalent for the Norwegian stock market, given the oil-importing character of the country. A clear difference in findings exists for the effects of the *precautionary demand* shocks. Interestingly, the latter shocks exercise a positive effect on Norwegian stock markets (although only in the short-run), whereas the opposite effect holds true for the Korean market.

As far as volatility is concerned, Jung and Park (2011) show that the responses are different between the two countries and among the three shocks. More specifically, they maintain that Norwegian stock market volatility responds favorably (i.e. reduces) to positive *aggregate demand* shocks, whereas insignificant effects are reported to *supply-side* and *precautionary demand* shocks. By contrast, it is only the *precautionary demand* shocks that lead to higher volatility in the case of the Korean stock market.

Furthermore, Wang *et al.* (2013) examine 16 stock markets (9 oil-importing and 7 oil-exporting) and find that, with the exception of Italy, none of the stock markets respond to *supply-side* oil price shocks; a finding which is in line with the previous literature. Furthermore, contrary to Jung and Park (2011), the authors do not find evidence of a positive response from oil-importing stock markets to positive *aggregate demand* shocks. The latter finding is similar to the conclusions of Apergis and Miller (2009). Nevertheless, their findings suggest that oil-exporting stock markets tend to respond positively to positive *aggregate demand* shocks. Finally, the results are inconclusive for *precautionary demand* shocks, given that for the majority of stock markets, the effects are insignificant. However, for four out of the seven oil-exporting stock markets (Canada, Saudi Arabia, Norway and Russia) the positive *precautionary demand* shocks trigger positive responses.

Overall, we observe that the literature (although scarce) points to the fact that stock market responses are heterogeneous to the different oil shocks, and also country-specific, depending on whether the country is an oil-importer or oil-exporter. These findings are justified by the fact that even though *aggregate demand* shocks are regarded as positive news, they also push production costs to higher levels for oil-importing economies, whereas higher oil prices provide greater incentives for investment and consumption in the oil-exporting country. Hence, *aggregate demand* shocks are more profound for the stock markets of oil exporters. Regarding the difference in stock market responses to *precautionary demand* shocks, this stems from the fact that even though such shocks are related to geopolitical tensions, the oil-exporting economy can have some short-term benefits from the increase in the price of oil.

4.2.3. Time-varying relationship

There is a recent strand of the literature which suggests that the aforementioned results may be time-varying. One of the early findings in this line of research is by Filis *et al.* (2011), who show that the correlation between oil and stock markets is time-varying and responds to the various oil price shocks. In particular, they show that *precautionary demand* (*aggregate demand*) shocks lead to lower (higher) correlations between oil and stock market returns and though the magnitude of these correlations is not always the same, suggesting that there is an element of event-specific effects. *Supply-side* events do not seem to trigger changes in the correlation. The results remain qualitatively similar for both oil-importing and oil-exporting economies.

A similar study is conducted by Degiannakis *et al.* (2013), who investigate ten European industrial sectors. They find that both the origin of the oil price shock as well as the type of the industry influence the time-varying correlation between oil and sectoral stock returns.

Broadstock and Filis (2014) employ a two-step procedure to investigate the time-varying relationship between oil price shocks and stock market returns for the US and China. They first extract the three oil price shocks using Kilian's (2009) framework, and then use the three shocks to assess whether their relationship with stock market returns is time-varying. This is the first study to explicitly show that the relationship between each of the three shocks and stock markets returns is indeed time-varying, and fluctuates between both positive and negative correlations. The only exemption is the correlation between the US stock returns and *aggregate demand* shocks, which always exhibit a positive correlation. The authors also proceed with the same analysis for select industrial sectors. Their evidence reveals that the relationships are time-varying and industry specific. The study also finds that the Chinese stock market seems to be more resilient to oil price shocks.

Finally, Kang *et al.* (2015b) employ a Time-Varying Parameter VAR model to investigate the time-varying effects of oil price shocks on US stock market returns. They show that in almost the whole study period (1973-2012) the *aggregate demand* (*precautionary demand*) shocks exercise a positive (negative) effect, although the magnitude of the effects diminish towards the latter part of the study. The *supply-side* shocks seem to have a significant negative effect in the early years (1973-1980), whereas marginal or insignificant effects are observed thereafter. Finally, the largest effect on stock market returns is observed from the *aggregate demand* shocks during the GFC.

4.3. Econometric methods and data used

All the aforementioned studies primarily use Kilian's (2009) Structural Vector Autoregressive (SVAR) model, which allows the identification of the three oil price shocks. The SVAR model uses three variables, namely global oil production, a global total spending variable (approximating *aggregate demand*) and US refiner's acquisition cost of crude oil (as a proxy for real oil prices).

More specifically, the global oil production variable is used to estimate the unexpected changes in oil production, which lead to *supply-side* oil price shocks.

The typical global *aggregate demand* proxy that the aforementioned studies use Kilian's global real economic activity index. The index is estimated using data from the dry cargo freight rates for bulk dry cargoes, which consist of coal, fertilizers, grain, oilseeds, iron ore and scrap metal. The index does not measure global output, but rather is a measure for global industrial commodities demand, as a result of worldwide economic activity (i.e. the global business cycle). The justification that Kilian (2009) puts forward is rather simple and quite convincing. Increasing freight rates suggests that the shipping industry operates closer to full capacity and this is true only during times of economic booms. By contrasts, during economic recessions, the demand for shipping reduces, which further leads to a reduction in the freight rates. To put it simply, increasing (decreasing) freight rates may indicate higher (lower) global demand. This index is utilized to capture the aggregate demand oil price shocks.

Finally, according to Kilian (2009), innovations to real oil prices that are not explained by either supply-side or aggregate demand oil price shocks should reflect changes in the demand for oil for reasons other than demand for industrial commodities or production changes by OPEC. Kilian (2009) suggests that the most plausible explanation is that these innovations can be explained by changes in the precautionary demand for oil and, thus, these are named precautionary demand shocks (also named as the oil-specific demand shocks or the idiosyncratic oil demand shocks).

Furthermore, studies that examine the time-varying relationship between oil shocks and stock market performance use either multivariate GARCH models (such as the Dynamic Conditional Correlation of Engle (2002) or BEKK by Baba et al. (1991) and Engle and Kroner (1995)) or the Time-Varying Parameter VAR model of Primiceri (2005).

4.4. Areas in need of future research

Table A.2 in the Appendix provides an overview of the literature which has been analyzed in this chapter. Despite the wealth of literature, there are several ways by which this line of research can be extended.

First and foremost, there is little evidence on the effects of the specific oil price shocks on firm-level stock returns. The less aggregation that exists in the data the less the possibility that the results may mask heterogeneity among industries and firms.

Furthermore, Kilian and Murphy (2012) and Kilian and Lee (2014) have established that another important oil price shock is the speculative shock, which derives from unexpected changes in global above ground oil inventories, possibly caused by the financialization of the oil market that has been observed over the last fifteen years or so (Fatthouh *et al*., 2012). Kilian and Murphy (2012) and Kilian and Lee (2014) maintain that participants in the oil market may well choose to store oil during times of low oil prices with the intention to release it when oil prices are anticipated to increase (or even simpler they may choose to go long in oil futures contracts). In simple terms, current and expected oil prices could create shifts in the speculative demand for oil. So far, there are no studies that have considered the effects of the speculative shocks on stock market returns and volatilities. Nevertheless, this is an important avenue for further study, given the financialization of the oil market and the increased participation of hedge funds in this market.

Finally, the majority of these studies concentrate either in the United States stock market or in a limited number of mature markets. Thus, there is plenty of scope to expand the evidence for emerging stock markets.

5. Relationship Between Oil Price Volatility and Stock Market Volatility

So far we have established the links between oil price returns/oil price shocks and stock market returns, either at aggregate or disaggregate levels (i.e. industrial sector or firm-level).

In this section, we turn our attention to the relationship between the volatilities of oil and stock markets. Ross (1989) maintains that volatilities from different assets can affect each other. Furthermore, Huang *et al.* (1996) opine that oil and stock market linkages could potentially be realized through their volatilities. Despite this *prima facie* evidence, only recently have researchers looked into the relationship between oil and stock market volatility (see for instance, Malik and Hammoudeh, 2007; Malik and Ewing, 2009).

This chapter begins by reviewing studies that focus on the static relationship between volatilities of the two markets (at either aggregate or disaggregate levels), and then proceeds to examine the relationship for oil-importing and oil-exporting countries. Next, we concentrate on their time-varying relationship, before discussing the various methodologies and data used in the empirical literature. The chapter concludes with ideas for further research.

5.1. Empirical evidence based on static approaches

5.1.1. Relationship between oil and stock market volatility

Malik and Ewing (2009) conduct one of the early studies in this line of research. The authors concentrate on six US sectoral stock market indices, namely Financials, Industrials, Consumer Services, Health Care and Technology, and examine the relationship between sector index volatilities and crude oil price volatility. Their findings suggest heterogeneous responses from the different sectoral indices; overall they report that oil price volatility positively affects sectoral stock market volatility. Nevertheless, no evidence of such effects is reported for Financial and Industrial sectors' volatilities.

Arouri *et al.* (2011a) also focus on several US and European industrial sectors (i.e. Automobile & Parts, Financials, Industrials, Basic Materials, Technology, Telecommunications and Utilities) for the period 1989-2009. Interestingly enough, the results are different not only among the different sectors (as already documented by Malik and Ewing, 2009), but also between the two financial markets. In particular, for European stock market volatility, the authors show that neither oil price volatility nor stock market volatility exercise any significant effects on one another. By contrast, oil volatility significantly impacts the industrial sector volatilities of Automobile & Parts, Basic Materials and Utilities sectors in the US, whereas no effects are reported for other sectors. On the other hand, none of the industrial sector volatilities seem to impact oil price volatility. In a subsequent study, Arouri *et al.* (2012) corroborate the findings of Arouri *et al.* (2011a).

So far, studies that focus on disaggregate indices show that oil market volatility exercises a significant impact at the sectoral level. Turning to studies that utilize aggregate stock market indices, Vo (2011) investigates the inter-dependence between S&P500 index and WTI crude oil price volatilities for the period 1999-2008. Contrary to previous evidence, the author finds a mutual inter-dependence between the two market volatilities. Similar results are also reported by Mensi *et al.* (2013), who examine the volatility linkages between stock and oil prices for both WTI and Brent crude oil prices. Mensi *et al*. (2013) find positive bidirectional effects between S&P500 and WTI volatilities, as in the case of Vo (2011). However, these results do not hold for the Brent volatility. More specifically, the findings suggest that it is the S&P500 volatility that exercises a significant effect on Brent crude oil volatility, rather than the reverse.

More recently, Ewing and Malik (2016) also support the findings of Vo (2011) and Mensi *et al.* (2013), focusing on WTI and S&P500 volatilities, for the period 1996-2013. It is evident from the study's results that there are significant cross-market volatility effects. Nevertheless, they also report that the oil price volatility receives stronger effects from the stock market volatility, as compared with the reverse. Furthermore, Phan *et al.* (2016) use volatilities from the futures contracts of the S&P500, NASDAQ and WTI and show that even in the futures markets, there are significant cross-market volatility effects.

A different approach is employed by Angelidis *et al.* (2015), who examine (among others) the impact of Brent crude oil volatility on the probability of the Dow Jones volatility being in a high risk regime. The authors cannot offer any support for the idea that oil price volatility exercises significant effects on stock market volatility.

5.1.2. Oil-importing countries and oil-exporting countries

Next, we concentrate on studies that have considered either oil-exporting or both oil-exporting and oil-importing countries in the same study.

Malik and Hammoudeh (2007) use data from 1994 to 2001 for the stock markets of the GCC region and WTI crude oil prices. Their findings show that GCC stock market volatilities are affected by oil price volatility, whereas the reverse does not hold true. The only exception is Saudi Arabia's stock market volatility, which is the only financial market volatility that exercises a significant effect on oil market volatility. According to the authors, such findings highlight the importance of Saudi Arabia in the global oil market.

Khalfaoui *et al.* (2015) use data for the stock market volatilities of the G7 countries, as well as, WTI crude oil price volatility. Even though the findings show interdependence between stock and oil volatilities, there is evidence to suggest that oil market volatility is leading stock market volatility. The authors are unable to find any heterogeneous effects between Canada (a major oil-exporting country) and the other G7 countries in the sample (oil-importers).

There are several other studies which focus on oil-exporting countries, but given that they examine the aforementioned relationship within time-varying frameworks, we report these in the following section (see Section 5.2).

5.2. Time-varying relationship between oil and stock market volatility

Thus far, the evidence reported in the previous sections does not capture possible heterogeneous relationships between oil price and stock market volatilities over different time periods. Hence, recent studies focus on the time-varying effects of relationships between volatilities of the two markets.

Arouri *et al.* (2011b) reveal that the relationship between the two volatilities is indeed time varying for GCC countries. More specifically, the oil market volatility significantly increases stock market volatility, and these effects are even more pronounced during the crisis period. Similarly, stock market volatility positively affects oil price volatility, although these effects disappear during tranquil periods. Awartani and Maghyereh (2013) provide support to the findings by Arouri *et al.* (2011b), as they also focus on the same stock markets and show that oil market volatility is the main transmitter of volatility shocks to stocks markets, rather than the reverse. These spillover effects are more apparent during the financial crisis.

Other studies that also concentrate on oil-exporting and oil-importing countries are those by Boldanov *et al.* (2016) and Maghyereh et al. (2016). Maghyereh et al. (2016) use a sample of 11 countries (3 oil exporters and 8 oil importers) for the period 2008-2015, and find evidence that oil price volatility is the main transmitter of volatility shocks to stock market volatilities, a finding similar to Awartani and Maghyereh (2013). The authors also do not report any distinction between oil-importing and oil-exporting countries.

By contrast, Boldanov *et al.* (2016) do report heterogeneous relationships between the oil and stock market volatilities of oil-importing and oil-exporting countries. In particular, even though the relationship between the two market volatilities is positive in the case of oil-importing countries, this does not hold for the oil-exporting countries. It is evident that during geopolitical unrest and natural disasters, the relationship between oil and stock market volatilities of oil exporters turns negative. Furthermore, the authors show that this relationship intensifies during periods of economic turbulence.

We finalize this section with two studies that focus solely on oil-importing economies. Du and He (2015) study the US market and show that there are significant risk spillovers between oil and stock markets. Disentangling the results further, they report that in the pre-financial crisis period these risk spillovers are positive and run from stock market volatilities to oil market volatilities. In parallel, there are also negative spillovers flowing from oil volatility to stock market volatility. Interestingly enough, these spillover effects change in the post-financial crisis period, where bidirectional positive spillover effects are reported. Bouri (2015), on the other hand, investigates four MENA countries (Lebanon, Jordan, Tunisia and Morocco) for the period 2003-2013. Overall, the findings reveal that there are not significant linkages between oil volatility and the volatilities of these MENA stock markets. This particularly holds for the pre-financial crisis period. Some evidence of significant linkages is reported in the post-financial crisis period, yet not for all countries. More specifically, bidirectional causality is evident between Jordanian stock market volatility and oil market volatility, whereas unidirectional causality running from oil volatility to Tunisian stock market volatility is also uncovered.

5.3. Econometric methods and data used

It is evident from the aforementioned studies that several different methods have been employed, as well as different sets of data.

More specifically, studies use both Brent and WTI crude oil prices, although the latter is more commonly employed. In terms of stock market data, the existing literature primarily uses aggregate stock markets for the US and GCC countries. Nevertheless, G7 countries and aggregate European stock market indices have been also considered. Finally, a small number of studies consider sectoral indices, but only for the US and Europe.

As far as data frequency is concerned, the majority of studies prefer the use of daily data, although there is a single study that has used intraday data (Phan et al., 2016). Finally, the volatility measure that is most commonly used in the studies is conditional volatility, rather than the realized volatility. There is only one study that has considered implied volatility indices (Maghyereh et al., 2016).

Turning our attention to the methods that have been used, the majority of the studies have employed a GARCH-type model, either in static frameworks (e.g. VAR-GARCH) or in time-varying frameworks (e.g. GARCH-BEKK, GARCH-VECH, Diagonal BEKK). However, studies which consider the time-varying relationship between the two market volatilities also consider the newly developed Spillover Index and Connectedness Index by Diebold and Yilmaz (2012 and 2014, respectively).

5.4. Areas in need of future research

Overall the findings from this chapter suggest that it is mainly oil price volatility that exercises a significant effect on stock market volatility, although evidence for the US shows the reverse also holds true. Furthermore, additional evidence suggests this relationship is time-varying, which tends to intensify during the global financial crisis period. A summary of these key findings can be found in Table A.3 in the Appendix.

Having reviewed a number of studies in this line of research, it is rather interesting that there are no studies that consider the relationship between oil and stock market volatilities using firm-level data. As also shown in Chapter 3, firm-level data offer rich information that could show firm heterogeneity even within the same sectoral index. Thus, there is scope to extend this strand of the literature using firm-level data.

Finally, some studies have already considered the portfolio implications of the relationship between oil and stock market volatilities (see, *inter alia*, Ewing and Malik, 2016; Khalfaoui *et al*., 2015; Arouri *et al.*, 2012; Arouri *et al*., 2011a). Nevertheless, the volatility measures used in these studies do not reflect tradable assets. Thus, another important avenue for further research is to focus on financial volatility measures that are actual tradable assets, so to make the recommendations more applicable to real world conditions.

6. Impact of Stock Markets on Forecasting Oil Prices and Oil Price Volatility

The final chapter of this report concerns the impact of stock market fluctuations on forecasting oil prices and oil price volatility. Recent evidence suggests that the oil market has experienced increased financialization, especially since the start of the 2000s (see, *inter alia*, Büyüksahin and Robe, 2014; Silvennoinen and Thorp, 2013; Fattouh *et al*., 2012). The term financialization stands for increased links between the oil and stocks markets.

The wealth of literature on oil price and oil price volatility forecasting does not use the information extracted from stock markets to examine whether it can provide incremental forecasting accuracy. Instead, studies rely mainly on oil market fundamentals like global oil production, global demand and global oil inventories[8], or the futures price of oil[9] when forecasting oil prices.[10] On the other hand, the literature on oil price volatility forecasting primarily uses past information about oil price volatility to forecast future volatility[11].

The remainder of this chapter is structured as follows. We start with studies that concentrate on oil price forecasting and then proceed with those focusing on oil price volatility forecasting. The chapter then reviews the econometric methods and the data employed. We conclude with ideas for future research.

6.1. Oil price forecasting

There are only three studies that examine the informational content of stock markets when forecasting oil prices. Chen (2014) uses the US AMEX Oil Index, the MSCI World Energy Sector Index for oil-sensitive stocks, and the S&P500 index to forecast monthly nominal and real crude oil prices—and to compare these forecasts against the no-change forecast (i.e. the random walk). The author uses various oil benchmarks (WTI, Brent and Dubai), as well as average world oil prices. The findings suggest that the US AMEX Oil Index and the MSCI World Energy Sector Index provide incremental forecasting ability for oil prices only in the short-run (i.e. 1-month ahead), as the no-change forecast is always superior for all forecasting horizons beyond 1-month.

The findings of Chen (2014) cannot be supported by Baumeister *et al*. (2015). In particular, these authors use a combination of low and high frequency data to forecast monthly real WTI crude oil prices. In particular, they use low frequency (monthly) oil prices and high frequency (daily) returns and the excess returns of oil company stocks (NYSE Oil Index). The authors compare the forecasting performance

[8] See, for instance, Baumeister and Kilian, (2015, 2014), Baumeister *et al*. (2014), Manescu and Van Robays (2014), Baumeister and Kilian (2012).

[9] E.g. Alquist and Kilian, (2010), Murat and Tokat (2009), Coppola (2008), Knetsch (2007).

[10] Zagalia (2010) maintains that the forecasting of oil prices may be biased when the impact of financial markets is ignored.

[11] See, for example, Prokopczuk *et al*. (2015), Sevi (2014), Chkili *et al*. (2014), Nomikos and Pouliasis (2011), Kang *et al*. (2009), Sadorsky (2006).

of these models based on stock market data against no-change forecasts, as well as those generated by models that use only oil market fundamentals. The authors find that the use of the returns and excess returns of the NYSE Oil Index offer marginally improved forecasts compared to the no-change forecast. Even more, they find that forecasts based on the NYSE Oil Index are not more accurate than forecasts based only on oil market fundamentals.

Furthermore, Yin and Yang (2016) use the dividend yield, dividend-price ratio and the earning-price ratio of the S&P500 Index, as well as the book-to-market value ratio for the Dow Jones Industrial Average to predict WTI crude oil prices. They compare these forecasts against others generated by technical indicators for oil prices (i.e. moving averages, the momentum and on-balance volume averages). Their findings show that technical oil price strategies have superior predictive accuracy compared to forecasts based on stock market indicators.

Finally, Degiannakis and Filis (2017) adopt a similar methodology with Baumeister et al. (2015) using (among others) daily returns and volatilities of major global stock markets to forecast monthly oil prices. In their study, the authors compared these forecasts against no-change forecasts as well as state-of-the-art models. Contrary to the findings by Baumeister et al. (2015), Degiannakis and Filis (2017) show that the use of high frequency stock market data (daily) provides incremental predictive accuracy to oil price forecasts, and incremental directional accuracy.

6.2. Oil price volatility forecasting

In terms of oil price volatility forecasting, there are again only three studies that examine whether the information extracted from stock markets can provide incremental forecasting accuracy.

More specifically, Efimova and Serletis (2014) use daily S&P500 returns to forecast the 1-day ahead WTI oil conditional volatility. The authors compare these forecasts against others generated by a random walk, past oil price volatility, oil price returns, natural gas price returns and electricity price returns. They report that univariate models based on the S&P500 daily returns cannot produce better oil price volatility forecasts compared with those based on gas and electricity price returns.

In addition, Phan et al. (2016) assess whether volatilities of the E-mini S&P500 index futures and the E-mini NASDAQ index futures can improve the forecasting accuracy of realized oil price volatility, compared to a model without any exogenous variables. Contrary to Efinova and Serletis, the authors show that cross-market volatility interaction increases the forecasting accuracy of oil price volatility.

More recently, Degiannakis and Filis (2016) show that the incorporation of stock market index volatility from the major global stock market indices (E-mini S&P500, FTSE100, Eurostoxx 50 and Hang Seng) does improve the forecasting and directional accuracy of Brent crude oil volatility compared to a random walk, as well as to models based only on past information of Brent crude oil price volatility.

6.3. Econometric methods and data used

Interestingly enough, there is not a common model that is used in the aforementioned studies. For instance, in the oil price forecasting literature Chen (2014) and Yin and Yang (2016) use predictive regression models[12], whereas Baumeister *et al*. (2015) and Degiannakis and Filis (2017) employ a Mixed-Data Sampling (MIDAS) framework, which allows the researcher to combine low and high frequency data in the same model.

On the other hand, in the oil price volatility literature Efimova and Serletis (2014) use multivariable GARCH models (such as BEKK and DCC), whereas Phan *et al*. (2016) use an EGARCH(1,1) model with and without exogenous variables. By contrast, Degiannakis and Filis (2016) employ a Heterogeneous Autoregressive (HAR) model with exogenous variables.

In terms of data, it is typical for authors to use WTI or Brent crude oil prices to measure oil price returns and volatility. Furthermore, the most common stock market data are from the US, including the S&P500 index and NASDAQ, although the US oil sector index is also commonly used.

Finally, there is not much consistency in the measurement of oil price volatility given that authors use both conditional and realized oil price volatilities.

6.4. Areas in need of future research

A summary of the studies presented in the section can be found in Table A.4 in the Appendix. It is evident from the scarce literature in this line of research that significantly more research should be conducted on the benefit of using the information content of stock markets in forecasting both oil prices and oil price volatility.

First, it would be interesting to assess whether non-US stock markets contain predictive information for oil price and oil price volatility forecasts. To this point only Degiannakis and Filis (2016) have used non-US stock market data, and the evidence is encouraging.

Another interesting avenue for further research is the production of density oil price and oil price volatility forecasts, based on information extracted from stock market fluctuations. Density forecasts are of particular importance for policy makers.

Furthermore, given that different global stock markets could contain predictive information for oil prices and oil price volatility, dimension reduction modelling could be employed in future forecasting exercises. This allows researchers to capture simultaneous information from various stock markets, without adding complexity to the models (e.g. too many exogenous variables) and avoids multicollinearity issues.

[12] A standard predictive regression model takes the form $y_{t+h} = a + \boldsymbol{b}\boldsymbol{x}_t + u_{t+h}$, where y_{t+h} denotes the oil price returns at time *t+h* (*h* is the out-of-sample *h*-step-ahead forecasts) and $\boldsymbol{x}_t$ is the vector of exogenous variables.

7. Conclusions and Implications

The aim of this report is to provide a detailed review of the literature on the relationship between oil and stock markets. We began with analysis of the transmission mechanisms between the two markets, and then proceeded to review literature on the effects of oil price fluctuations on stock market returns. Subsequently, we discussed the role of oil prices shocks on stock market performance and the interconnectedness between the volatilities of the two markets. Finally, we moved to analyze the informational content of stock markets for forecasting oil prices and oil price volatility.

The main conclusions that can be drawn from the aforementioned analysis are as follows:

- There are various channels that impact firm cash flow and/or their discount rates. These transmission channels suggest that higher oil prices lead to lower stock market returns—for stock markets operating in oil-importing economies. The reverse applies for oil-exporting countries. Further study in this area should concentrate on the possible asymmetric effects of positive and negative oil price changes. Additionally, theoretical transmission channels by which stock markets affect oil prices should be also developed.
- Evidence mainly supports this theory, showing that higher oil prices lead to lower stock market returns in oil-importing countries, and higher stock market returns in oil-exporting countries. At a more detailed level, higher oil prices due to supply-side or precautionary demand shocks trigger negative responses from stock markets, whereas higher oil prices resulting from a boost in the global economy (aggregate demand shocks) are received as positive news by stock markets. More recent evidence shows that the relationship between the two markets is time-varying. Nevertheless, there is scope to further expand this line of research by assessing the aforementioned effects (i) over the whole distribution of returns, (ii) as to whether they are direct or indirect and (iii) when considering firm-level data.
- Oil price volatility exercises a significant effect on stock market volatility, whereas the reverse holds true only in the case of the US market. Furthermore, additional evidence suggests that the volatility relationship is time-varying, which tends to intensify during the global financial crisis period. Interestingly, there are no studies that focus on firm-level data when considering volatility interconnectedness between the two markets, making this is an interesting avenue for further research.
- Furthermore, despite the importance of oil prices for the global economy, the linkages between oil and stock markets (either in returns or in volatilities), as well as the fact that these markets exhibit a dynamic relationship, there is a small number of studies that have evaluated the information content of stock markets in forecasting both oil prices and oil price volatility. Thus, significant more research is required in this line of research, especially utilizing data of higher frequencies, which contain rich information on both the oil and stock markets.

Finally, the in-depth review that is carried out in this report provides information on the implications of these findings for portfolio holders. In short:

- There is some evidence to suggest that the oil market can provide hedging opportunities for stock markets. Nevertheless, more evidence needs to be accumulated on whether these findings hold at the firm-level, and whether the reverse hedging opportunities still apply (i.e. whether stock markets function as a hedging tool for oil price fluctuations). In addition, future studies should increase further in the applicability of the literature's results for investment purposes by focusing on optimal weight allocation for multi-asset portfolios, as well as real financial assets such as index futures, ETFs of stock indices, etc.
- As aforementioned, the volatilities of the two markets are linked together in a dynamic fashion. Taking into consideration that there are assets which mirror the performance of their volatilities (e.g. ETFs or futures contracts on implied volatility indices), research should examine the implications of this time-varying volatility interconnectedness for volatility investors.
- The oil market has become more financialized in recent years due to the increased participation of hedge funds. Thus, studies should investigate further the role of the speculative activity in the oil market and how this financialization has altered its nature.

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Appendix

Table A.1. Summary of the literature review of Chapter 3

Authors	Methodology	Data and oil specifications	Countries	Findings
		Symmetric effects of oil price fluctuations		
Phan *et al.* (2015)	GARCH(1,1)	Top-20 listed firms listed in the construction, air transport, truck transport, chemical manufacturing and petroleum sectors, top-60 firms listed in the CONGEP sub-sector, WTI crude oil prices	US	Increased oil prices increase oil producers' stock prices and decreases oil consumers' stock prices.
Filis and Chatziantoniou (2014)	VAR	Brent crude oil prices, CPI, Short-run interest rates, stock market indices.	UK, Germany, Italy, Spain, Netherlands, Portugal, Russia, Norway	Oil-importing stock markets respond negatively to positive oil price changes, whereas the reverse holds for the oil-exporting stock markets. The magnitude of stock market responses to oil price changes is higher for the newly established and/or less liquid stock markets (such as Russia and Norway).
Miller and Ratti (2009)	VECM	Brent crude oil prices, Producer price indices, Stock market indices, CPI, IPI, Short-run interest rates.	US, Germany, UK, Italy, France, Canada	Stock market prices increase when oil prices decrease and the reverse. This relationship becomes less clear between 1999 and 2008.
Henriques and Sadorsky (2008)	VAR	WilderHill Clean Energy Index, The Arca Technology Index, WTI crude oil prices, 3 month US T-bills.	US	Oil price changes have a small impact on the alternative energy and technology companies.
Sadorsky (2001)	Multifactor market model	Toronto Stock Exchange Oil & Gas Index, WTI crude oil prices, 90-day Canadian T-bill, 30-day Canadian T-bill.	Canada	Increases in oil prices tend to increase the stock prices of the Oil & Gas index.

Table A.1. Summary of the literature review of Chapter 3 (cont.)

Authors	Methodology	Data and oil specifications	Countries	Findings
Narayan and Sharma (2011)	GARCH	560 US firms level stock prices from different sectors, US-Euro nominal exchange rate, Short-term interest rates, oil prices, NYSE stock market index.	US	Sectors such as Supply, Manufacturing, Food, Chemical, Medical, Computer, Transportation, Real Estate and General Services respond negatively to positive oil price changes, whereas inconclusive findings are reported for the Electricity, Engineering and Financial sectors.
Papapetrou (2001)	VAR	IPI, 12-month T-bill, Real oil prices, Industrial Employment, Real stock price index.	Greece	Real stock returns respond negatively to positive real oil price changes.
Asymmetric effects of oil price fluctuations				
Broadstock *et al.* (2014)	CAPM-GARCH	TOPIX, TOPIX Oil sub-index, NIKKEI225, NIKKEI 500 Oil sub-index, SENSEX I, SENSEX I Oil and Coal sub-index, SENSEX II, SENSEX II Power sub-index, KOSPI, KOSPI 200 Energy and Chemical sub-index, TWSE, Taiwan Taiex Oil, Electricity and Gar sub-index, WTI Crude oil prices, SOPI, SPOD, NOPI	Japan, India, Korea, Taiwan	Stock markets exhibit greater responses to positive changes in oil prices (e.g. Tokyo, Korea and Taiwan). Authors maintain that different specifications for capturing the asymmetric effects of oil prices could yield different results and, thus, authors should be very careful when choosing the asymmetric specification.
Park and Ratti (2008)	VAR	Real stock market indices, real Brent crude oil prices, CPI, Industrial production indices, short-term interest rates, SOPI, SOPD, NOPI	Germany, Belgium, Spain, Greece, Sweden, UK, Finland, Italy, Denmark, Norway, US	US stock market responds heterogeneously to positive and negative oil price changes. Not enough evidence of such heterogeneity for the European stock markets.

Table A.1. Summary of the literature review of Chapter 3 (cont.)

Authors	Methodology	Data and oil specifications	Countries	Findings
Narayan and Gupta (2015)	Linear regression models	S&P500 stock market index, Positive and negative WTI crude oil price returns	US	There is evidence of oil price asymmetric effects, given that negative changes in oil prices allow for superior prediction of stock price returns, compared to the positive changes.
Oil-importing vs. Oil-exporting countries				
Arouri and Rault (2012)	Bootstrap panel cointegration techniques and seemingly unrelated regression	Stock market indices, OPEC spot prices	Bahrain, Oman, Kuwait, Qatar, Saudi Arabia, United Arab Emirates.	Long-run and positive relationships between oil prices and GCC stock markets
Bjornland (2009)	VAR	OSEBX, OSEAX, Real and Nominal Brent crude oil prices, NIBOR, Unemployment rate, CPI, Real effective exchange rate, Trade weighted three month foreign interest rate.	Norway	Higher oil prices leads to higher stock market returns.
Hammoudeh and Li (2005)	VECM, APT	NYMEX 3-month oil futures prices, MSCI, US Amex Oil Index, US NYSE Transportation Index, Mexico IPC Index, Oslo All-Share Index	US, Mexico, Norway	Increased oil prices are detrimental for world capital markets and transportation stocks, whereas they exert a positive impact on oil-related stocks.

Table A.1. Summary of the literature review of Chapter 3 (cont.)

Authors	Methodology	Data and oil specifications	Countries	Findings
Lescaroux and Mignon (2008)	Panel cointegration, Panel Granger-Causality, VAR	GDP, CPI, Household consumption, unemployment rate, stock market indices, real crude oil prices from the BP Statistical Review.	36 countries (OPEC, Non-OPEC oil exporting economies and 12 major oil importing economies).	Causality runs from oil prices to stock market returns, especially for the oil-exporting countries. Oil and stock market returns of the non-OPEC countries have a long-run relationship, as well.
Time-varying relationship				
Degiannakis *et al*. (2013)	Diag-VECH GARCH model	Stock market indices for Financials, Oil & Gas, Retail, Consumption Goods, Health, Industrial, Basic Materials, Technology, Telecommunications and Utilities sectors, Brent crude oil prices.	European Union	Time-varying relationship between oil and stock returns for all industrial sectors, regardless whether these are oil-users, oil-related, oil-substitutes and non-oil-related.
Chang *et al*. (2013)	VARMA-GARCH, VARMA-AGARCH, DCC, CCC	WTI and Brent crude oil prices (futures and spot), FTSE100, NYSE, Dow Jones Industrials Index, S&P500.	UK, US	Evidence of time-varying correlations between oil and stock market returns, which reaches a peak during the global financial crisis. Correlations for Dow Jones and FTSE100 are mainly positive.
Filis *et al*. (2011)	DCC-GARCH-GJR model	Stock market indices, Brent crude oil prices.	Canada, Mexico, Brazil, US, Germany, Netherlands	Geopolitical unrest leads to a negative correlation between oil price changes and stock market returns, whereas during recessions or economic booms the relationship turns positive.

Table A.1. Summary of the literature review of Chapter 3 (cont.)

Authors	Methodology	Data and oil specifications	Countries	Findings
Sadorsky (2012)	BEKK, CCC, DCC, VARMA-GARCH	WilderHill Clean Energy Index, the Arca Technology Index, WTI crude oil futures prices.	US	Correlations between oil and sectoral index stock returns are time-varying, which reach a peak and maintain high positive values since the global financial crisis.
Broadstock *et al*., 2012	BEKK, CAPM	Brent crude oil prices, Energy sector index, Oil & Gas index, Coal and Electricity index, New energy index.	China	Evidence of time-varying correlations between oil and sectoral stock market returns, which reaches a peak during the global financial crisis. Correlations fluctuate at both positive and negative values.

Table A.2. Summary of the literature review of Chapter 4

Authors	Methodology	Data	Countries	Findings
Abhyankar *et al.* (2013)	Structural VAR	World oil production, Global real economic activity, Japanese Crude Cocktails prices, Datastream's Japanese country equity index	Japan	*Aggregate demand* (*precautionary demand*) shocks exercise a positive (negative) effect of stock market returns
Angelidis *et al.* (2015)	Structural VAR, Markov Regime Switching, Probit regression model	World oil production, Global real economic activity, Brent crude oil prices, Dow Jones index	United States	Positive *supply-side* and *aggregate demand* shocks push the US stock market returns in bull territory, whereas positive *precautionary demand* shocks lead to higher US stock market volatility
Apergis and Miller (2009)	Structural VAR	World oil production, Global index of dry cargo single voyage freight rates, Brent crude oil prices, Australian General Market Index, C.L. Toronto Index, DAX index, CAC Industrial Index, Milan IB 30 index, Nikkei Stock Index, Financial Times 30 index, and NYSE index.	Australia, Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States	International financial markets do not really value oil shocks

Table A.2. Summary of the literature review of Chapter 4 (cont.)

Authors	Methodology	Data	Countries	Findings
Basher *et al.* (2012)	Structural VAR	World oil production, Global real economic activity, WTI crude oil price, MSCI emerging stock market index, TED Spread, US trade-weighted exchange rates	Emerging economies	Emerging stock markets do not seem to react to the *supply-side* shocks, whereas a positive response is observed for both the *aggregate demand* and *precautionary demand* shocks.
Broadstock and Filis (2014)	Structural VAR, Scalar-BEKK model	World oil production, Global real economic activity, Brent crude oil price, S&P500, Shanghai Composite index, Banking, Metals & Mining, Oil & Gas, Retail and Technology industrial indices	China, United States	The relationship between each of the three shocks and stock markets returns is time-varying and fluctuates at both positive and negative correlations.
Degiannakis *et al.* (2013)	Diag-VECH GARCH model	Financials, Oil & Gas, Retail, Consumption Goods, Health, Industrial, Basic Materials, Technology, Telecommunications and Utilities industrial indices	European Union	Oil and industrial stock returns correlations exhibit heterogeneous pattern under different oil price shocks and different industries.

Table A.2. Summary of the literature review of Chapter 4 (cont.)

Authors	Methodology	Data	Countries	Findings
Degiannakis *et al.* (2014)	Structural VAR, Realized Volatility measure, APARCH	World oil production, Global real economic activity, Brent crude oil prices, Eurostoxx 50, Financials, Oil & Gas, Retail, Consumption Goods, Health, Industrial, Basic Materials, Technology, Telecommunications and Utilities industrial indices	European Union	Stock market volatility responds negatively (i.e. reduces) to positive *aggregate demand* shocks, whereas no significant response is evident to *supply-side* and *precautionary demand* shocks
Filis *et al.* (2011)	Dynamic Conditional Correlation	Brent crude oil prices, S&P/TSX 60, MXICP 35 , Bovespa Index, Dow Jones Industrial, DAX 30, AEX General Index	Brazil, Canada, Germany, Mexico, Netherlands, United States	*Precautionary demand* (*aggregate demand*) shocks lead to lower (higher) correlations between oil and stock market returns. The magnitude of these correlations are event-specific. The *supply-side* events do not seem to trigger changes in the correlation.
Gupta and Modise (2013)	Structural VAR	World oil production, Global real economic activity, US refiner's acquisition cost of crude oil, Johannesburg Securities Exchange Allshare Index	South Africa	Negative *supply-side* shocks exercise a negative effect on the stock market. Positive *aggregate demand* (*precautionary demand*) shocks lead to positive (negative) stock returns

Table A.2. Summary of the literature review of Chapter 4 (cont.)

Authors	**Methodology**	**Data**	**Countries**	**Findings**
Jung and Park (2011)	Structural VAR	World oil production, Global real economic activity, Brent crude oil price, Oslo Stock Exchange All Share Index, NOK/USD exchange rate, KOSPI Index, KRW/USD exchange rate	Norway, Korea	*Supply-side* oil price shocks do not impact stock market returns. Heterogeneous responses are reported for the two demand side shocks (i.e. *aggregate demand* and *precautionary demand* shocks).
Kang *et al.* (2015a)	Structural VAR	World oil production, Global real economic activity, US refiner's acquisition cost of crude oil, CRSP value-weighted stock returns, VIX	United States	Positive *aggregate demand* and *precautionary demand* shocks lead to lower covariability between the returns and volatility of the US market. *Supply-side* shocks are not transmitting any impact. The two demand-side shocks also lead to lower stock market volatility.
Kang *et al.* (2015b)	Time-varying parameter structural VAR model	World oil production, Global real economic activity, US refiner's acquisition cost of crude oil, CRSP value-weighted stock returns	United States	*Aggregate demand* (*precautionary demand*) oil price shocks exercise a positive (negative) effect, although the magnitude is time-varying. *Supply-side* shocks exercised a negative effect from 1973-1980, whereas no effect is reported for the period 1980-2012.

Table A.2. Summary of the literature review of Chapter 4 (cont.)

Authors	Methodology	Data	Countries	Findings
Kang *et al.* (2017)	Structural VAR	World oil production, Global real economic activity, US refiner's acquisition cost of crude oil, Royal Dutch Shell, Exxon Mobil, BP, Chevron, ConocoPhillips, TransCanada Corporation, Valero Energy Corporation (VLO) stock prices, Fama-French oil and gas index prices	United States	The Oil & Gas index, as well as, the individual firms, react negatively to negative *supply-side* shocks and to positive *precautionary demand* shocks, whereas they react positively to positive *aggregate demand* shocks.
Kilian and Park (2009)	Structural VAR	World oil production, Global real economic activity, US refiner's acquisition cost of crude oil, CRSP value-weighted stock returns, Petroleum & Natural Gas index returns, Automobiles & Trucks index returns, Retail index returns, Precious Metals index returns	United States	Aggregate stock market returns do not respond to *supply-side* shocks, whereas positive (negative) responses are observed during *aggregate demand* (*precautionary demand*) shocks. Heterogeneous responses to oil price shocks are reported for the different industrial indices.
Wang *et al.* (2013)	Structural VAR	World oil production, Global real economic activity, WTI crude oil price, S&P 500, NIKKEI 225, DAX, CAC 40, FTSE 100, FTSE MIB, Shanghai Composite, KOSPI Composite, BSE Sensex, Tadawul All Share, Kuwait Stock Exchange Index, Bolsa IPC, OSEAX, MICEX, IBVC, S&P/TSX Composite	United States, Japan, Germany, France, United Kingdom, Italy, China, Korea, India, Saudi Arabia, Kuwait, Mexico, Norway, Russia, Venezuela, Canada	None of the stock markets respond to the *supply-side* oil price shocks. Oil-exporting stock markets respond positively to positive *aggregate demand* shocks. Results are inconclusive for the *precautionary demand* shocks, as for the majority of the stock markets, the effects are insignificant.

Table A.3. Summary of the literature review of Chapter 5

Authors	Methodology	Data	Countries	Findings
Angelidis et al. (2015)	Markov Regime Switching Regression	Dow Jones, Brent crude oil (monthly 1989-2011)	United States	Oil volatility does not exercise a significant effect on stock market volatility
Arouri et al. (2011a)	VAR-GARCH	Brent crude oil, Dow Jones Stoxx Europe 600, S&P500, Sectoral Indices of both countries (Automobile & Parts, Financials, Industrials, Basic Materials, Technology, Telecommunications, and Utilities). (daily data 1989-2009)	Europe and United States	Europe: no effects between oil and stock market volatility. USA: Unidirectional effects are evident. Oil volatility significantly impacts industrial sectors volatilities for Automobile & Parts, Basic Materials and Utilities.
Arouri et al. (2011b)	VAR-GARCH	Brent crude oil, Stock market indices of Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and UAE (daily data 2005-2010)	GCC countries	Oil market volatility significantly increases stock market volatility, although these effects are intensified during crisis period. Stock market volatility also positively affects oil price volatility but not during tranquil periods.
Arouri et al. (2012)	VAR-GARCH	Brent crude oil, Dow Jones Stoxx Europe 600, Sectoral Indices (Automobile & Parts, Financials, Industrials, Basic Materials, Technology, Telecommunications, and Utilities). (weekly data 1989-2009)	Europe	No evidence of spillover effects between oil and stock market volatility.
Awartani and Maghyereh (2013)	Diebold and Yilmaz Spillover index	WTI crude oil, Stock market indices of Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and UAE (daily data 2004-2012)	GCC countries	Oil market volatility transmits more shocks to the stocks markets rather than the reverse. Spillover effects are more pronounced during the financial crisis.

Table A.3. Summary of the literature review of Chapter 5 (cont.)

Authors	Methodology	Data	Countries	Findings
Bouri (2015)	ARMAX–GARCH	Brent crude oil, Lebanese, Tunisian, Jordanian and Moroccan stock market indices, MSCI World Index	Lebanon, Jordan, Tunisia, Morocco	Pre-crisis: Stock market volatility not responsive to oil market volatility. Post-crisis: Bidirectional causality between Jordanian stock market volatility and oil market volatility. Unidirectional causality from oil volatility to Tunisian stock market volatility.
Du and He (2015)	Granger Causality	S&P500, WTI crude oil (daily data 2004-2012)	United States	Significant risk spillovers between the oil and stock market. Pre-crisis: Positive spillovers from stock market volatility to the oil market volatility. Negative spillovers from the oil volatility to the stock market volatility. Post-crisis: Bidirectional positive spillover effects.
Ewing and Malik (2016)	GARCH, BEKK	WTI crude oil, S&P500 (daily data 1996-2013)	United States	Significant cross-market volatility effects, which are more important than own past-volatilities. Oil volatility, though, receives stronger effects from the stock market volatility than the reverse.
Khalfaoui et al. (2015)	GARCH-BEKK, Wavelet-based GARCH-BEKK	S&P/TSX, CAC40, DAX, FTSE-MIB, NIKKEI225, FTSE100, S&P500, WTI (daily data 2004-2012)	G7 countries	Inter-market volatility spillover effects, although WTI is the leading market.
Maghyereh et al. (2016)	Diebold and Yilmaz connectedness index	Implied volatility indices for Canada, India, Japan, Germany, Russia, USA, UK, Mexico, Sweden, South Africa, Switzerland and WTI (daily 2008-2015)	Canada, India, Japan, Germany, Russia, USA, UK, Mexico, Sweden, South Africa, Switzerland	Oil volatility exercises a stronger effect to stock market volatilities, compared to the reverse.

Table A.3. Summary of the literature review of Chapter 5 (cont.)

Authors	Methodology	Data	Countries	Findings
Malik and Ewing (2009)	Bivariate GARCH	Dow Jones sectoral indices (Financials, Industrials, Consumer Services, Health Care, Technology), WTI crude oil (weekly data 1992-2008)	United States	Heterogeneous responses from the different industrial sectors. Overall, oil market volatility positively impacts stock market volatility.
Malik and Hammoudeh (2007)	GARCH-VECH	WTI crude oil, Stock market indices of Bahrain, Kuwait and Saudi Arabia (daily data 1994-2001)	GCC countries	GCC stock market volatilities are affected by oil price volatility. Only Saudi Arabia stock market volatility affects oil market volatility.
Mensi et al. (2013)	VAR-GARCH	S&P500, WTI crude oil, Brent crude oil (daily data 2000-2011)	United States	Positive bidirectional effects between WTI volatility and S&P500 volatility. Positive unidirectional effects from S&P500 volatility to Brent volatility.
Phan et al. (2016)	EGARCH	Intraday data for E-mini S&P500 index futures, E-mini NASDAQ index futures and WTI futures	United States	Significant cross-market volatility effects.
Vo (2011)	VAR with Stochastic Volatility	S&P500, WTI crude oil (daily data 1999-2008)	United States	Inter-market dependence in volatility.

Table A.4. Summary of the literature review of Chapter 6

Authors	Methodology	Data	Findings
Oil price forecasting			
Chen (2014)	Predictive regression models	US AMEX Oil Index, MSCI World Energy Sector Index, WTI crude oil, Brent crude oil, Dubai crude oil.	US AMEX Oil Index and the MSCI World Energy Sector Index provide incremental forecasting ability for the oil prices only in the short-run.
Baumeister et al. (2015)	MIDAS	WTI crude oil prices, NYSE Oil Index.	The use of the returns and excess returns of the NYSE Oil Index offer marginally improved oil price forecasts compared to the no-change forecast.
Yin and Yang (2016)	Predictive regression models	Dividend yield, dividend-price ratio and earnings-price ration of the S&P500 index, book-to-market ratio of the Dow Jones Industrial Average, WTI crude oil prices.	Oil price technical strategies have superior predictive accuracy compared to forecasts based on the stock market indicators.
Degiannakis and Filis (2017)	MIDAS	Tick-by-tick futures data for Brent crude oil, E-mini S&P500, FTSE100, Hang Seng, Eurostoxx 50.	The use of stock markets' high frequency data provides incremental predictive accuracy to oil price forecasts, as well as, incremental directional accuracy.

Table A.4. Summary of the literature review of Chapter 6 (cont.)

Authors	Methodology	Data	Findings
Oil price volatility forecasting			
Efinova and Serletis (2014)	BEKK, DCC	WTI crude oil prices, S&P 500 index	The use of S&P500 daily returns does not improve the forecasting accuracy of the oil conditional volatility.
Phan et al. (2016)	EGARCH	Tick-by-tick futures data for Brent crude oil prices, E-mini S&P500, E-mini NASDAQ	Cross-market volatility interaction increases the forecasting accuracy of the oil price realized volatility.
Degiannakis and Filis (2016)	HAR-RV-X models	Tick-by-tick futures data for Brent crude oil, E-mini S&P500, FTSE100, Hang Seng, Eurostoxx 50.	The use of stock market volatility data improves the forecasting accuracy of the Brent crude oil price realized volatility.