Oil Price Risk Exposure at Industry and Subsector Levels: A Case Study

Komeil Shaeri

Submitted to the
Institute of Graduate Studies and Research
in partial fulfillment of the requirements for the degree of

Doctor of Philosophy
in
Finance

Eastern Mediterranean University
July 2016
Gazimağusa, North Cyprus

Approval of the Institute of Graduate Studies and Research

Prof. Dr. Cem Tanova
Acting Director

I certify that this thesis satisfies the requirements as a thesis for the degree of Doctor of Philosophy in Finance.

Assoc. Prof. Dr. Nesrin Özataç
Chair, Department of Banking and Finance

We certify that we have read this thesis and that in our opinion it is fully adequate in scope and quality as a thesis for the degree of Doctor of Philosophy in Finance.

Prof. Dr. Cahit Adaoğlu
Co-supervisor

Prof. Dr. Salih Katırcıoğlu
Supervisor

Examining Committee

1. Prof. Dr. Cahit Adaoğlu
2. Prof. Dr. Sami Fethi
3. Prof. Dr. Fazıl Gökgöz
4. Prof. Dr. Salih Katırcıoğlu
5. Prof. Dr. M. Banu Durukan Salı

ABSTRACT

This thesis consists of two separate studies. The first study examines the oil price risk exposure of U.S. financial and non-financial industries over the period of January 1983 to March 2015 at the subsector level. The oil price risk factor is appended to the Fama and French (2015) five-factor asset pricing model. The magnitude of oil prices' impact on the financial subsectors is considerably lower than the magnitude of its impact on the non-financial subsectors. Among the non-financial subsectors, Airlines and Oil Equipment Services have the largest negative and positive oil price risk exposures, respectively. The time-varying oil price risk exposure of these subsectors is estimated using a time-varying parameter model in state-space form. Moreover, via the rolling window causality test introduced by Hill (2007), the time-varying causality in return is estimated. The second study investigates the interaction between crude oil prices and the stock prices of oil, technology, and transportation companies listed on U.S. stock exchanges, using weekly data covering the period from January 2, 1990 to February 3, 2015. Considering the importance of regime shifts or structural breaks in econometric analysis, this study employs the Carrion-i-Silvestre et al. (2009) unit root tests and the Maki (2012) cointegration tests allowing for multiple breaks. Cointegration results confirm the existence of long-run equilibrium relationships between these stock indices, crude oil prices, short-term interest rates and the S&P 500.

Keywords: Oil price risk exposure; equity returns; multiple structural breaks; Fama-French five-factor model; state-space model; time-varying causality; cointegration

ÖZ

Bu tez iki kısımdan oluşmaktadır. Birinci kısım Amerikan Borsanın petrol fiyatları riskinin etkisini mali ve mali olmayan endüstri üzerinde 1983 Ocak ile 2015 Mart dönemi içerisinde sektörel bazda inceler. Fama ve French'in (2015) Beş Faktörlü Varlık Fiyatlama modeli kullanılarak petrol fiyatları risk faktörü belirlenmeye çalışılmıştır. Mali alt sektörlerdeki petrol fiyatları etkisinin büyüklüğü mali olmayan sektörlere göre çok daha düşük bulunmuştur. Mali olmayan alt sektörler arasında Havayolları ve Petrol Araç-gereç Servisleri hem en büyük negative hemde positif petrol fiyatlerı risk etkisine sahip olan alt-sektörlerdir. Parameter modeli kullanılarak alt sektörlerdeki zaman içinde değişen petrol fiyatlerı risk etkisi tahmin edilmiştir. Ayrıca, Hill (2007) nedensellik testi kullanılarak zaman içerisinde değişen nedenleri tahmin etmiştir. Tezin ikinci kısmı ham petrol fiyatları, borsadaki petrol fiyatları, teknoloji ve ulaştırma şirketleri arasındaki ilişkiyi haftalık veriler kullanılarak 1990 Ocak ile 2015 Şubat dönemi içerisinde endüstri bazda inceler. Bu kısımda Carrion-i-Silvestre ve diğ. (2009) Birim Kök testi ve Maki (2012) eşbütünleme testi uygulanarak yapısal değişikliklerin etkisi ölçülmeye çalışılmıştır. Eşbütünleme testinin sonuçları ışığında borsa endeksleri, ham petrol fiyatları, kısa dönem faiz oranları ve S&P 500 endeksi arasında, uzun dönemli denge ilişkisi bulunmuştur.

Anahtar Kelimeler: Petrol fiyatları risk etkisi, özkaynak getirileri, çoklu yapısal kırılmalar, Fama-French Beşli Faktör modeli, devlet-uzay modeli, nedensellik testi, eşbütünleme testi

TO MY WIFE

ACKNOWLEDGMENT

I would like to express my utmost gratitude to Allah, the merciful and compassionate, for giving me good health, wisdom, wellbeing, knowledge, those were necessary to complete my education.

I also would like to appreciate my supervisor Prof. Dr. Salih Katırcıoğlu for his valuable and helpful suggestions during the preparation of this thesis.

I would like to express my sincere gratitude to my co-supervisor Prof. Dr. Cahit Adaoğlu for his immense knowledge, motivation, and patience. I am deeply indebted to him for the continuous encouragement and care that he gave, enabling me to finish this thesis.

I also would like to acknowledge Prof. Dr. Sami Fethi for his help, support and constructive suggestions during the completion of this thesis.

Last but not least, I would like to express my earnest gratefulness to my wife Samaneh for her love, inspiration, and understanding throughout my education. My parents, Moloud and Ghorbanali, receive my heartfelt appreciation and love for their dedication and commitment. Frankly, none of this would have been imaginable without the love, support and patience of my family.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1

INTRODUCTION

Energy has acted a momentous role in the economic development of almost all the countries. Out of few energy sources, crude oil is the main resource being substantially used throughout the world. It is also considered as an essential driver of contemporary economic activities. Several factors are responsible for crude oil price variations which can be listed as the world demand for oil by developed and emerging markets, supply conditions of oil exporting countries, and energy security concerns due to political instability in the oil-rich nations.

The outlook of the crude oil market is not completely clear since the largest oil reserves are not situated on the territory of the largest oil-consuming countries. Almost 60% of the global oil consumption occurs in North American and Asia Pacific countries. However, they only hold 15% of the total global proved oil reserves. Contrariwise, countries like Saudi Arabia, Iran, Iraq, Kuwait, and United Arab Emirates have almost 50% of the world's proved oil reserves, while they account for less than 10% of the world's oil consumption (BP, 2015). Hence, it can be suggested that Middle East has a significant role in the global energy market.

Furthermore, member-nations of the Organization of the Petroleum Exporting Countries (OPEC) possess almost 81% of the world's proved oil reserves (1,200 billion barrels), and their respective governments control these reserves through their national oil companies (OPEC, 2014). This creates a great opportunity for these countries to pursue their petropolitics in line with their national and international interests, thus benefiting from this natural wealth. Since, most OPEC member-nations are located in geopolitical hotspots; their political instability and social unrest create concerns about energy security for the larger oil-consuming countries.

According to Mussa (2000), higher oil prices have an adverse effect on the world economy. He indicates that a $5 per barrel rise in the oil price can probably shrink the world output by roughly 0.25% within the first 4 years. In the same way, International Energy Agency is also suggesting that a $10 rise in the oil price would lower the global GDP by 0.5% in the year following (IEA, 2004). This is because higher oil prices may lead to higher incomes for the oil-exporting countries but in turn, these increased earnings would be less than its negative impact on the economies of the oil-importing countries.

Historically, the volatility in crude oil prices has had a significant impact on economic activities (Mork, 1994). A large body of literature has been developed examining the interactions between oil price fluctuations and economic activities (e.g., Hamilton, 1983; Gisser and Goodwin, 1986; Cunado and Perez de Gracia, 2005; Cologni and Manera, 2008; Hamilton, 2009; Kilian, 2009). Specifically, studies have shown that oil price fluctuations influence equity prices via at least two channels. First, since oil is one of the most important inputs in the production of many goods and services, any volatility in its price influences future cash flows.

Higher oil prices increase production costs, decreasing future cash flows and reducing equity prices (Sadorsky, 1999; Apergis and Miller, 2009; Arouri and Nguyen, 2010). Second, the discount rate used in stock valuation models is affected by oil price changes. Central banks usually control the inflationary pressures of higher oil prices by raising the interest rates, and higher interest rates ultimately exert a negative impact on share prices via higher discount rates (Huang et al., 1996; Miller and Ratti, 2009; Mohanty et al., 2011).

Furthermore, unpredictability of crude oil prices can influence risk premiums demanded by investors on assets that have higher oil price risk exposures. Sensitivity of stocks to oil prices can negatively or positively influence their prices based on the sign of a firm's exposure to oil prices. These reasons justify a comprehensive sectoral investigation focusing on the interdependence of equity returns and crude oil prices.

In general, the way that we compute the oil price risk whether at the firm, subsector, sector or industry levels, and also the sign of the oil risk premiums determine the overall impact of oil price on the stock markets. Undoubtedly, such implications cannot be made using market level data since by combining all the stocks, important features of industries, sectors, and subsectors cannot be uncovered. A number of studies have evaluated the exposure of stock markets to oil price risk at the aggregate level (e.g., Kling, 1985; Chen et al., 1986; Jones and Kaul, 1996; Wei, 2003; Park and Ratti, 2008; Sorensen, 2009; Gogineni, 2009; Miller and Ratti, 2009; Kilian and Park, 2009; Dhaoui and Khraief, 2014).

Some of the studies have examined the sensitivity of industry equity returns to oil price risk (e.g., Sadorsky, 2001; Nandha and Faff, 2008; Nandha and Brooks, 2009; Gogineni, 2010; Mohanty and Nandha, 2011a, b; Bredin and Elder, 2011; Aggarwal et al., 2012; Mohanty et al., 2013). Hence, the principal aim of this thesis is to offer an ample study covering both industry- and subsector-level analyses in order to reveal their oil price risk exposures from the standpoint of the asset pricing theory.

1.1 Energy Market Review

Being curious about the energy market and following its related news, is not just for energy companies, it is something which affects all of us. The future condition of energy market is very important for almost all of the countries. Many dimensions of lives are affected by energy such as heating, electricity, industrial production, transportation, lubricants, and petrochemical materials. Therefore, it is very crucial to have an idea about the future path of energy market. Actually, in order to have this insight, we should be able to anticipate the future conditions of the population, economy, energy sources, technological advances, and political situation of energy producing countries. Otherwise, it is impossible to understand the climate of the energy market.

1.1.1 Global Energy Market

In this section, the ins and out of the World energy market will be reviewed from both producers' and consumers' perspectives. Global primary energy production increased from 8580 MTOE (Million Tons of Oil Equivalent) in 1995 to 13273 MTOE in 2015 and it is expected to rise to 17279 MTOE in 2035. Figure 1 shows the outlook of global energy production on regional basis. This figure illustrates the historical and forecasted production of all types of energy sources till 2035 (BP Energy Outlook, 2016).

As you can see, although the energy production has been rising up through the whole period but the production growth rate of all the energies declined in the period of 2005-2015 compared with the period of 1995-2005 except for hydroelectricity and renewables. It shows that the production growth of oil decelerated from 19.95% in 1995-2005 to 10.17% in 2005-2015. The production growth of natural gas also slowed from 32% to 26.60%, for coal from 34% to 26.08%, and for nuclear from 19.12% to -5.86% between the aforementioned periods.

On the other hand, the production growth for hydroelectricity increased from 17.53% in 1995-2005 to 34.25% in 2005-2015 and for renewables from 127.26% to 317.66%. This shows more demand tendency toward these two types of energies. Surprisingly, both of these energies are considered as green energy sources. Remarkably, the production growth of renewables skyrocketed by more than two folds between these two periods which indicates the importance this type of energy in the future.

According to this outlook, by 2035, Middle East will still remain as the largest producer of oil followed by North America. Inversely, North America will become the largest natural gas producer followed by Middle East in 2035. Moreover, Asia Pacific region will be the largest producer of coal, nuclear, hydroelectricity, and renewables in 2035. Figure 2 presents the outlook of global energy consumption by fuel on regional basis.

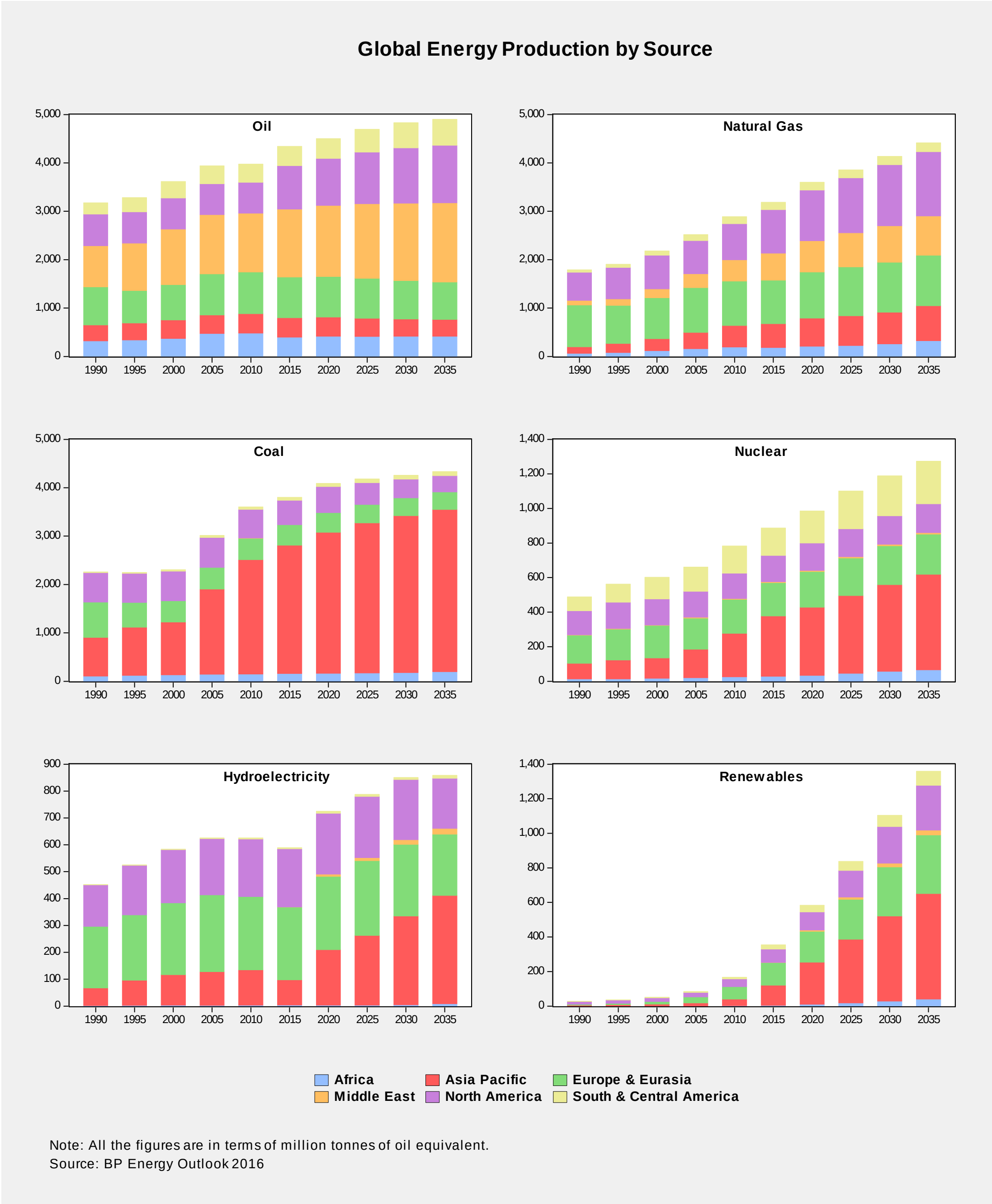


Figure 1. The outlook of global energy production by source

Global energy consumption increased from 8600 MTOE in 1995 to 13080 MTOE in 2015 and it is expected to rise to 17307 MTOE in 2035. This figure illustrates the historical and forecasted consumption of all types of fuels till 2035 (BP Energy Outlook, 2016). Oil is the world's prevailing fuel with 32.6% of global energy consumption, but its market share has been reduced in the last 15 years. The oil industry comprises subsectors such as exploration, extraction, production, refining and transportation. The result of interconnectedness between these subsectors is the input for the other industries.

This indicates that other industries are heavily dependent on the outputs of the oil industry such as petrochemical materials, various types of liquid fuels, asphalt, tar, lubricants and many other products. Thus, it is an important concern for many countries to have access to oil or oil derivatives. Since its discovery till now, it has been considered as one of the most strategic commodities for all countries. Beside from its financial benefits, some countries use oil as a multirole weapon to reach different political goals in the international scene (Graf, 2012). The OPEC oil embargo of 1974 against Israel and its allies is the best example for this case.

Therefore, the "petropolitics" of the oil exporting countries displays the substantial role of oil in today's world. As you can see in Figure 2, while the energy consumptions have been growing through the whole period but the consumption growth rate of all the energies (fuels) dropped in the period of 2005-2015 compared with the period of 1995-2005 except for hydroelectricity and renewables. It shows that the consumption growth of liquid (oil-based) fuels slowed from 19.08% in 1995-2005 to 9.54% in 2005-2015.

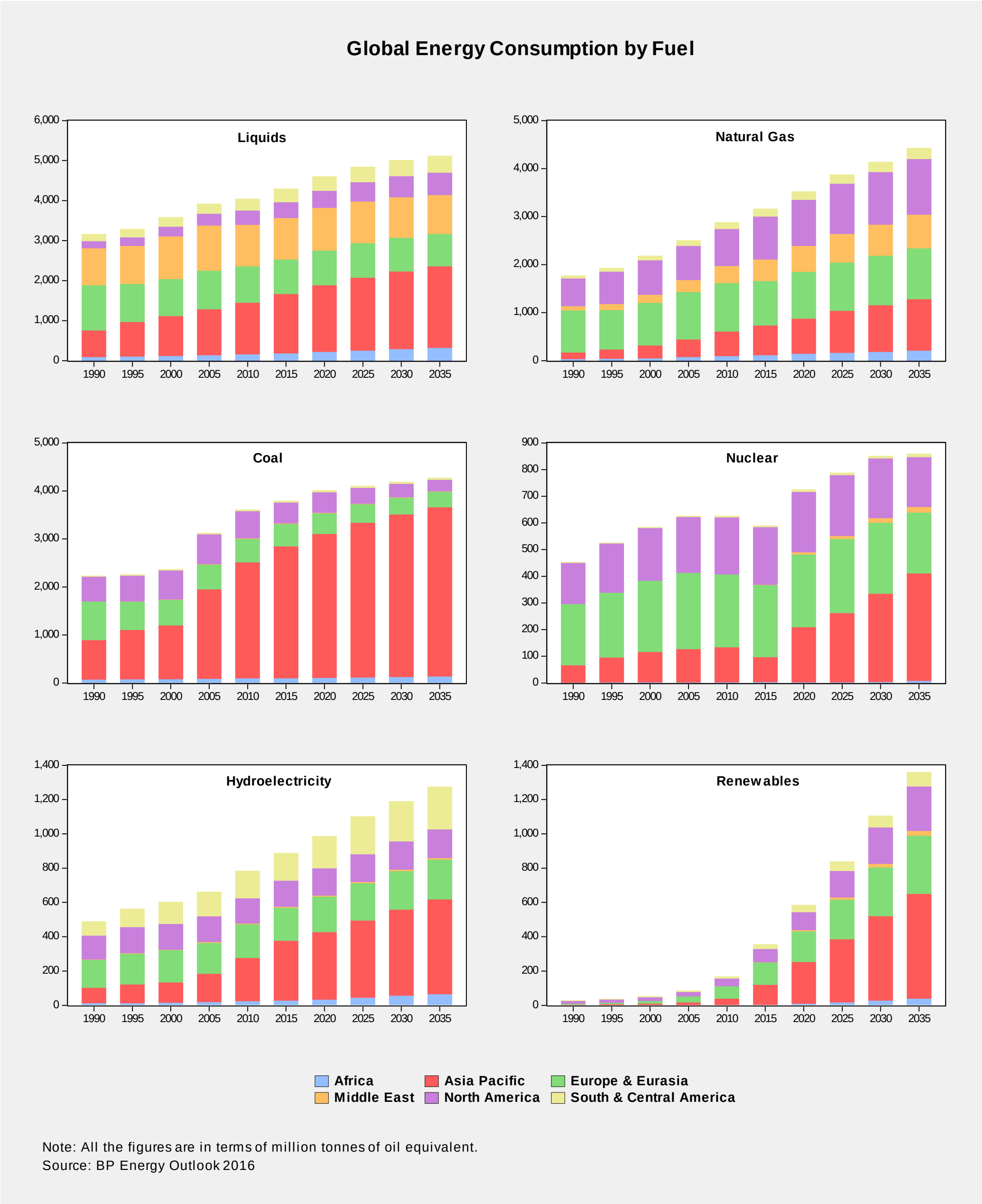
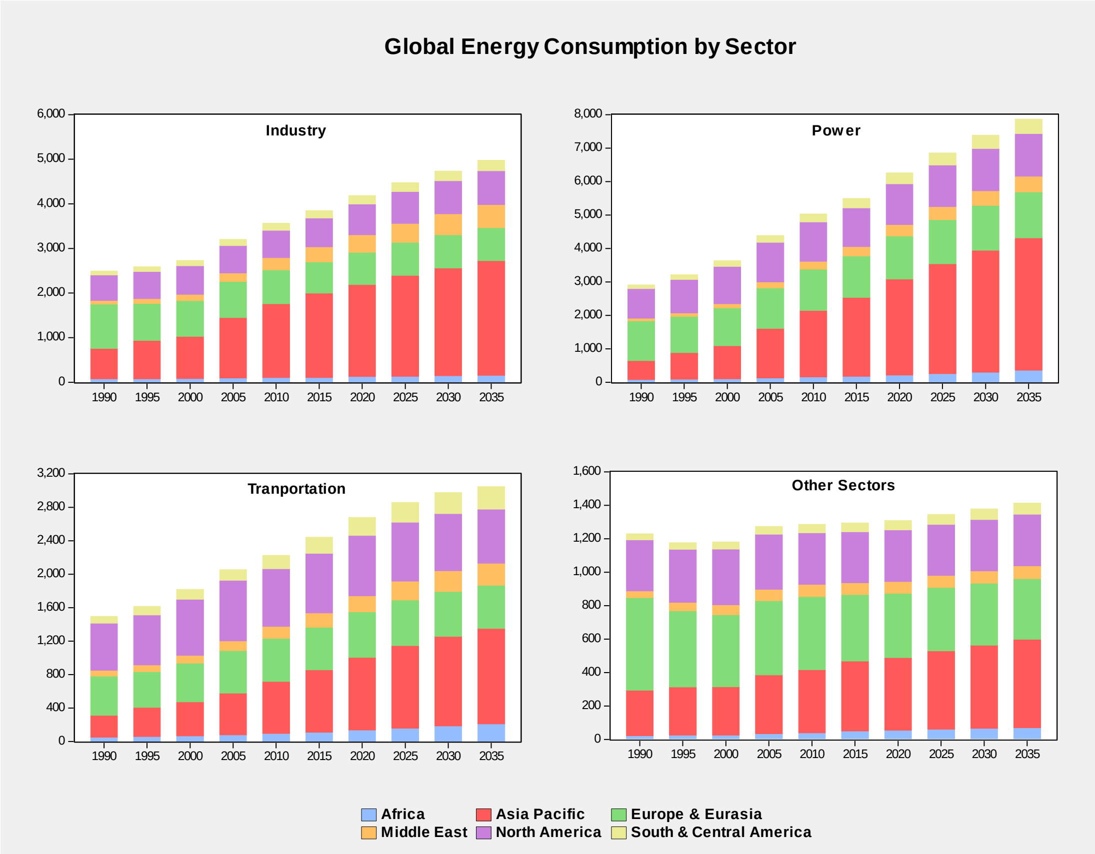


Figure 2. The outlook of global energy consumption by fuel

The consumption growth of natural gas also slowed from 30.15% to 26.14%, for coal from 38.30% to 21.54%, and for nuclear from 19.12% to -5.86% between the aforementioned periods. In contrast, as it is mentioned before, the consumption growth for hydroelectricity increased from 17.53% in 1995-2005 to 34.25% in 2005-2015 and for renewables from 127.26% to 317.66%. According to this outlook, by 2035, Asia Pacific will still remain as the largest consumer of liquid fuels followed by Middle East. Additionally, North America will surpass Europe & Eurasia and become the largest natural gas consumer in 2035.

Moreover, Asia Pacific region will be the largest consumer of coal, nuclear, hydroelectricity, and renewables in 2035. Figure 3 displays the outlook of global energy consumption in terms of industry, power, transportation, and other sectors. The power generation sector is the largest consumer of energy followed by industry, transportation and other sectors. According to this outlook, Asia Pacific region is the biggest energy consumer in all sectors in 2015 and it will remain like this up to 2035.

Like the previous figures, although the energy consumptions of these sectors have been growing but the consumption growth rate slowed between two periods of 1995-2005 and 2005-2015. For the industry sector it reduced from 23.67% to 20.19%, for the power sector from 36.32% to 25.20%, for the transportation sector from 27.27% to 18.85, and for the other sectors from 8.27% to 1.66%. This diminishing production and consumption growth rates can be linked to several factors such as the slower global economic growth, improving efficiency in the industry, transportation and power generation sectors.



Note: All the figuresare in termsof million tonnesof oil equivalent.
Source: BP Energy Outlook 2016

Figure 3. The outlook of global energy consumption by sector

1.1.2 The U.S. Oil Market

In this thesis, the impact of oil prices on the U.S. industry subsectors will be examined. For this reason, it is necessary to review the U.S. oil market before further progress. The West Texas Intermediate (WTI) is the crude oil produced in the U.S. and considered as a benchmark in crude oil pricing market along with Brent crude oil and OPEC Reference basket. It is also known as “Texas light sweet” due to its relatively low density (light) and its low sulfur (sweet) content. It is lighter and sweeter than Brent crude oil. The main trading hub for WTI crude oil is the city of Cushing, Oklahoma. For the last three decades, Cushing has been the price settlement point for crude oil contracts and also a delivery point for WTI on the New York Mercantile Exchange (CME Group, 2016).

Figure 4 shows the historical prices of WTI during 1983M01 to 2016M01 along with the major events which affected the oil market. These major events can be listed as follows:

OPEC excess supply (1985)

End of Iran-Iraq war (1988)

First Persian Gulf war (1990)

The U.S. recession (1990-91)

Asian financial crisis (1997)

Russian financial crisis (1998)

OPEC production cutbacks (1999)

The U.S. recession (2001)

9/11 Attacks (2001)

Venezuelan labor unrest (2002-03)

Second Persian Gulf war (2003)

Hurricane Katrina (2005)

Hurricane Rita (2005)

Oil price spike (2007)

Global financial crisis (2008-09)

OPEC cutbacks (2009)

The onset of Arab Spring (2011)

Global excess supply of oil (2014-15)

West Texas Intermediate crude oil ($/bbl)

Note: shaded areas show recessions in the U.S.
Source: Datastream

Figure 4. History of WTI (January 1983 to January 2016)

The infographic of the U.S. oil industry in 2015 is illustrated in Figure 5. As you can see, U.S. became the largest crude oil producer in the World in 2015 by producing 11.6 million barrels per day. By the end of 2015, the U.S. share of global oil reserves is 2.9%, its share of global oil production is 12.3%, its share of global oil refinery is 18.4% and its share of global oil consumption is 19.9%.

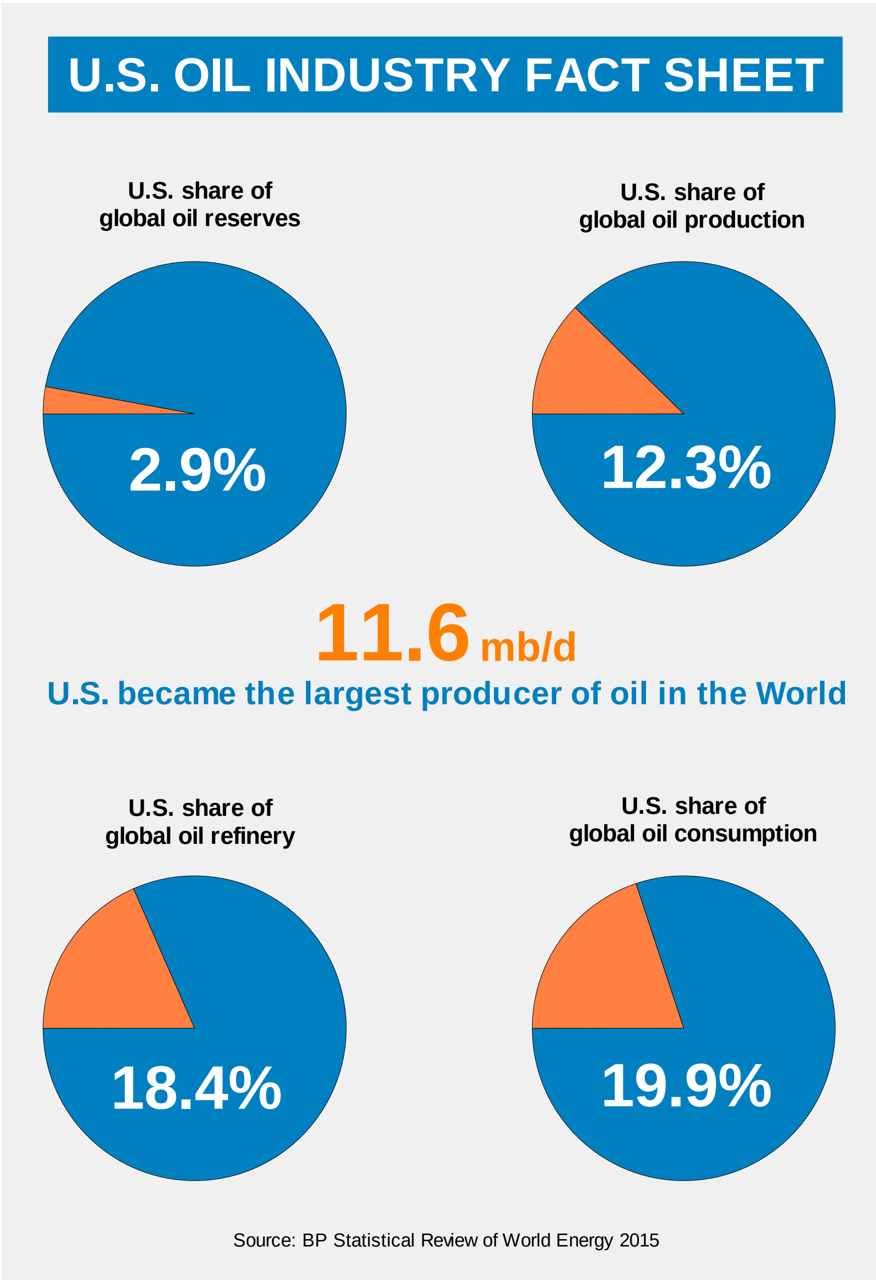


Figure 5. The U.S. oil industry fact sheet in December 2015

1.2 Aim and Importance of the Study

The earlier studies have mainly focused on the impact of crude oil prices on the oil, gas, and transportation companies and industries. Henceforth, there is a momentous gap in the literature for an all-encompassing study that takes into account the impact of crude oil prices on all industries and their subsectors. In the first study, it is tried to ascertain which subsectors in both financial and non-financial industries are relatively highly exposed to oil price risk by using various econometrics and risk measurement techniques. The models and approaches which have been used in this study can be enumerated as Fama and French five factor model, breakpoint regression with the ability to detect multiple structural breaks, GED-EGARCH, value-at-risk (VaR), and time-varying causality in return and risk.

In the second study, the nexus between crude oil prices and the stock prices of the listed U.S. oil, technology, and transportation companies has been investigated by using weekly data. Taking into consideration the importance of structural breaks or regime shifts in econometric analysis, this study hires the Carrion-i-Silvestre et al. (2009) unit root tests and the Maki (2012) cointegration tests allowing for multiple breaks. The cointegration test is used to examine the presence of long-run equilibrium relationships among these stock indices and crude oil prices. Later, the dynamic OLS (DOLS) approach can be used to estimate the long-run coefficients for the stock indices of oil, technology and transportation companies and crude oil prices. Using the Bai and Perron (2003) test and breakpoint regression, the oil price exposure of these companies can be estimated in a regime-dependent manner.

1.3 Structure of the Study

The remainder of this thesis is organized as follows. Chapter 2 presents the first study entitled as “oil price risk exposure: a comparison of financial and non-financial subsectors”. Chapter 3 gives the second study dubbed as “the nexus between oil prices and stock prices of oil, technology and transportation companies”. Chapter 4 concludes these studies and provides some policy implications.

Chapter 2

OIL PRICE RISK EXPOSURE: A COMPARISON OF FINANCIAL AND NON-FINANCIAL SUBSECTORS

2.1 Introduction

The impact of crude oil prices on the economy has always been the center of attention for various reasons. Mork (1994) asserts that the volatility in crude oil prices has had a significant impact on economic activities. The relevant literature is filled with studies examining the nexus between oil price fluctuations and economic activities (e.g., Hamilton, 1983; Gisser and Goodwin, 1986; Cunado and Perez de Gracia, 2005; Cologni and Manera, 2008; Hamilton, 2009; Kilian, 2009). Particularly, some papers have shown that oil price variations affect stock prices through at least two channels. As crude oil is one of the most key inputs in the production of various goods and services, any instability in its price impacts forthcoming cash flows.

The second way which permits crude oil to affect equity prices is the use of discount rate in asset valuation models. The interest rate has always been as one of most crucial tools in the hands of central banks to limit the inflationary pressures of higher oil prices. In order to avoid these pressures, they usually raise interest rates which eventually have an adverse effect on equity prices as it is raising discount rates (Huang et al., 1996; Miller and Ratti, 2009; Mohanty et al., 2011).

These whys and wherefores vindicate an ample sectoral analysis aiming on the interdependence of crude oil prices and equity returns. As it is mentioned before, some researchers have done aggregate-level studies to assess the exposure of equity markets to oil price risk (e.g., Kling, 1985; Chen et al., 1986; Jones and Kaul, 1996; Wei, 2003; Park and Ratti, 2008; Sorensen, 2009; Gogineni, 2009; Miller and Ratti, 2009; Kilian and Park, 2009; Dhaoui and Khraief, 2014). Some other works have inspected the sensitivity of equity returns to oil price risk at the industry level (e.g., Sadorsky, 2001; Nandha and Faff, 2008; Nandha and Brooks, 2009; Gogineni, 2010; Mohanty and Nandha, 2011a, b; Bredin and Elder, 2011; Aggarwal et al., 2012; Mohanty et al., 2013). Nonetheless, the majority of these studies have focused on the oil, gas, and transportation industries.

Hence, there is a significant gap in the literature for a comprehensive study that takes into account the effect of crude oil prices on all industries and their subsectors. This study aims to determine which subsectors in both financial and non-financial industries are relatively highly exposed to oil price risk. Mohanty and Nandha (2011a) studied the U.S. oil and gas industry and demonstrated that the extent of oil price exposure differs across its subsectors and over time. Similarly, Mohanty et al. (2014) assessed the oil price sensitivity of all the subsectors within the U.S. travel and leisure industry. They concluded that the oil price sensitivities of subsectors differ considerably. Nevertheless, to the best of our knowledge, no previous study has measured and compared the oil price risk exposure of the financial and non-financial industries by conducting a comprehensive subsectoral analysis. Such an analysis is important because an industry-level study may not capture the true influence of oil price changes on each subsector.

This study contributes to the literature in four ways. First, the oil price risk exposures of both financial and non-financial subsectors are examined and compared. Second, this study covers all available industry subsectors in the U.S. economy according to the Datastream industry classifications at level six. Third, the sensitivity of industry subsectors to oil prices is examined using the newly introduced Fama and French (2015) five-factor asset pricing model (FF5F). Fourth, a multifactor asset pricing model is tested under the presence of multiple structural breaks. In this study, we use the approach of Bai and Perron (2003) to identify the structural breaks in the relationship between equity returns of subsectors and the multifactor model variables for the period of January 1983 to March 2015.

The time-varying oil price risk exposure of these subsectors is estimated the by using a time-varying parameter model in state-space form. This study yields some noteworthy results. First, the majority of financial and non-financial subsectors are affected by oil price changes. However, though the magnitude of the impact is quite limited on average, the degree of oil price sensitivity differs noticeably across subsectors and over time. Second, the magnitude of oil price exposure of the financial subsectors is considerably lower than the magnitude of oil price exposure of the non-financial subsectors.

Third, the majority of the financial subsectors (10 out of 12 significant subsectors) are negatively affected by oil prices while most of the non-financial subsectors (14 out of 20) are positively affected. Fourth, only 12 out of 20 financial subsectors exhibit a statistically significant exposure to the price of oil in at least one of the sub-periods, whereas for the non-financials, all of the 20 most sensitive subsectors show a statistically significant exposure to the price of oil. Fifth, for the both types of subsectors, the monthly return on the market portfolio (MKT) has the highest share among other risk factors in determining the subsectors' returns. However, the monthly return on West Texas Intermediate crude oil (OIL) has the least important role in explaining the subsectors' returns for the both financials and non-financials. Empirically, Fama and French (1993) show that the their three-factor model (FF3F) performs better in explaining the stock returns, and the systematic risk factor of beta (β) in the theoretical capital asset pricing model (CAPM) does not fully capture the systematic risk associated with individual stocks or stock indices.

They show that in addition to the beta (β) risk factor, factors such as firm size and book-to-market ratio can be good proxies for measuring the systematic risk not completely captured by CAPM (i.e., the FF3F model). Subsequently, Fama and French (2015) extend the FF3F model to five-factor model (FF5F) by adding two more factors (i.e., profitability and investment patterns). The results show that, in addition to the oil risk exposure factor, the return premiums (factor loadings) of these factors are statistically significant in explaining the stock index returns.

Sixth, by applying the method of time-varying causality in return, it is found that after the 1990-91 and 2008-09 recessions, there are high levels of causality in return running from oil market to financial and non-financial subsectors. Seventh, by employing the method of time-varying causality in risk, it is confirmed that there are high levels of risk spillover effect running from the oil market toward financial and non-financial subsectors during and after the 2008-09 financial crisis.

2.2 Literature Review

Chen et al. (1986) were among the first researchers to examine the oil price sensitivity of equity returns in the U.S. over the period 1958–1984, and they show that oil prices do not significantly affect equity returns. Similarly, by using the U.S. daily data, Huang et al. (1996) show that oil price changes have no significant effect on either the aggregate or industry levels over the period 1983–1990. Sadorsky (2001) investigates the oil price exposure of Canadian oil and gas industry stocks over the period of 1983M04–1999M04. He uses a multifactor market model and estimates it using ordinary least squares (OLS) regression.

He shows that some risk elements, such as oil prices, interest rates, and market index, determine the equity returns of the Canadian oil and gas industry. Click (2001) studies the long-run nexus between equity returns of oil companies and oil price fluctuations for the period 1979–1999. He concludes that oil price risk explains the equity returns of oil companies. Hammoudeh and Li (2004) confirm that oil price is a determining factor in explaining the equity returns of the U.S. oil and transportation industries. They also find similar results for the stock markets of Norway and Mexico. Via a multifactor framework, Boyer and Filion (2007) analyze the influence of oil price shocks on equity returns of oil and gas companies in Canada. They estimate a multifactor model using generalized least squared (GLS) regression, and their results indicate that the equity returns of this industry are positively affected by natural gas and oil prices. They also assert that the oil and natural gas risk exposures of these stocks vary significantly over time.

In an industry-level study, Nandha and Faff (2008) evaluate 35 worldwide equity indices over the period 1983M04–2005M09. They demonstrate that stock returns of all sectors, except for the mining, and oil and gas sectors, are negatively affected by oil price shocks. Kilian (2008) estimates the effects of oil price shocks on the restaurant and lodging industry and finds them to be adverse. He also gives evidence regarding the negative influence of energy price shocks on the airline industry. Park and Ratti (2008) inspect the effect of oil price shocks on the equity markets of the U.S. and thirteen European states over 1986M01–2005M12. They employ a vector autoregressive (VAR) methodology and show that oil price shocks significantly affect real equity returns. They find that only in Norway, an oil exporting country, the equity market reacts positively to a positive oil price shock.

Miller and Ratti (2009) examine the long-term nexus between oil prices and equity markets of six OECD countries for the period 1971M01–2008M03 using a vector error correction model (VECM). After finding evidence for breaks in the data, they divide the period of the study into three sub-periods. For the two sub-periods of 1971M01–1980M05 and 1988M02–1999M09, they find that stock market indices negatively respond to positive oil price shocks. However, during 1980M06–1988M01, stock market indices do not significantly react to positive oil price shocks.
At the industry level, Gogineni (2010) finds that oil-intensive industries are the most sensitive ones to oil prices. Moya-Martínez et al. (2014) inspect the exposure of the stock market to oil price fluctuations in Spain for the period 1993–2010. Under the presence of structural breaks, they study the Spanish market at the industry level. According to their results, Spanish industries have limited exposure to oil price changes, but these results vary across industries.

They find that in the 1990s, a period of relatively low oil prices with low volatility, the sensitivity of industries to oil prices is very weak. However, during the 2000s, the nexus between stocks and crude oil prices have increased. Mohanty et al. (2014) assess the oil price sensitivity of the U.S. travel and leisure industry at the subsector level. They employ the four-factor asset pricing model of Carhart (1997), which is based on the prominent FF3F model plus a momentum factor. They embed the oil price as a risk factor into this model. Their results indicate that the oil price sensitivities of these subsectors (i.e., Airlines, Hotels, Gambling, Recreational Services, Restaurants & Bars, and Travel & Tourism) vary considerably but they are generally negative.

By incorporating dummy variables for the recessions in the model, they also show that the 2007–2009 financial crisis had a crucial impact on the oil price sensitivity of the Airlines subsector. Tsai (2015) examine the reaction of stock returns to oil price shocks before, throughout, and after a financial crisis. He uses daily data of 682 U.S. firms for the period of 1990M01 to 2012M12. By using the firm-level data, he confirms the asymmetric effects of oil price shocks on stock returns throughout and after the crisis. During and after the crisis, the oil-intensive industries are more positively affected by oil price shocks compared to the less oil-intensive industries. In order to examine the impact oil price shocks across various firm sizes, he employs different proxy variables such as the number of employees, total revenue, and total assets. The results indicate that oil price shocks affect the big size firms more significantly and negatively prior to the crisis. However, medium size firms are positively affected by oil price shocks in the post-crisis period.

Using a cross-sectional data, Demirer et al. (2015) investigate the oil price risk exposure in the stock markets of net oil exporting countries for the period of 2004M03 to 2013M03. They incorporate both the oil price risk factor and an idiosyncratic volatility factor into the FF3F model. The results show that the oil-sensitive stocks harvest significantly higher returns indicating that oil price exposure can be used as a predictor of stock returns in the Gulf Cooperation Council (GCC) stock markets.

2.3 Data and Methodology

2.3.1 Data

This study investigates the oil price exposure of the U.S. industry subsectors over the period of January 1983 to March 2015. Monthly stock price indices of the subsectors are obtained from the Datastream. According to the Datastream industry classification of level six (subsector level), there are a total of 109 subsectors, and all are included in this study. These subsectors are divided into two categories: financials (20 subsectors) and non-financials (89 subsectors). Table 1 shows the Datastream industry classification hierarchy. Datastream divides the whole economy into 10 industries namely, Oil & Gas, Basic Materials, Industrials, Consumer Goods, Health Care, Consumer Services, Telecommunications, Utilities, Financials, and Technologies. Also, these 10 industries are divided into 19 supersectors, 40 sectors, and 109 subsectors. The Fama-French factors are obtained from Kenneth French's data library ttp://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.htm). For the oil price, we use the monthly returns on the West Texas Intermediate (WTI), expressed in USD/barrel. WTI is selected for two reasons. First, in North America, it is the most widely used benchmark for crude oil prices. Second, most of the hedging instruments used by North American companies, such as futures, forwards, and other derivatives, are based on the WTI.

Table 1. Datastream industry classification hierarchy

Industry	Supersector	Sector	Subsector
Oil & Gas	Oil & Gas	Oil & Gas Producers	Exploration & Production
			Integrated Oil & Gas
		Oil Equipment, Services & Distribution	Oil Equipment & Services
			Pipelines
		Alternative Energy	Renewable Energy Equipment
Basic Materials	Chemicals	Chemicals	Commodity Chemicals
			Specialty Chemicals
	Basic Resources	Forestry & Paper	Forestry
			Paper
		Industrial Metals & Mining	Aluminum
			Nonferrous Metals
			Iron & Steel
		Mining	Coal
			Gold Mining
			Platinum & Precious Metals
Industrials	Construction & Materials	Construction & Materials	Building Materials & Fixtures
			Heavy Construction
	Industrial Goods & Services	Aerospace & Defense	Aerospace
			Defense
		General Industrials	Containers & Packaging
			Diversified Industrials
		Electronic & Electrical Equipment	Electrical Components & Equipment
			Electronic Equipment
		Industrial Engineering	Commercial Vehicles & Trucks
			Industrial Machinery
		Industrial Transportation	Delivery Services
			Marine Transportation
			Railroads
			Transportation Services
			Trucking
		Support Services	Business Support Services
			Business Training & Employment Agencies
			Financial Administration
			Industrial Suppliers
			Waste & Disposal Services
Consumer Goods	Automobiles & Parts	Automobiles & Parts	Automobiles
			Auto Parts
			Tires
	Food & Beverage	Beverages	Brewers
			Distillers & Vintners
			Soft Drinks
		Food Producers	Farming & Fishing
			Food Products
	Personal & Household Goods	Household Goods & Home Construction	Durable Household Products
			Nondurable Household Products
			Furnishings
			Home Construction
		Leisure Goods	Consumer Electronics
			Recreational Products
			Toys
		Personal Goods	Clothing & Accessories
			Footwear
			Personal Products
		Tobacco	Tobacco

Table 1. Continued

Industry	Supersector	Sector	Subsector
Health Care	Health Care	Health Care Equipment & Services	Health Care Providers Medical Equipment Medical Supplies
		Pharmaceuticals & Biotechnology	Biotechnology Pharmaceuticals
Consumer Services	Retail	Food & Drug Retailers	Drug Retailers Food Retailers & Wholesalers
		General Retailers	Apparel Retailers Broadline Retailers Home Improvement Retailers Specialized Consumer Services Specialty Retailers
	Media	Media	Broadcasting & Entertainment Media Agencies Publishing
	Travel & Leisure	Travel & Leisure	Airlines Gambling Hotels Recreational Services Restaurants & Bars Travel & Tourism
Telecommunications	Telecommunications	Fixed Line Telecommunications	Fixed Line Telecommunications
		Mobile Telecommunications	Mobile Telecommunications
Utilities	Utilities	Electricity	Conventional Electricity Alternative Electricity
		Gas, Water & Multiutilities	Gas Distribution Multiutilities Water
Financials	Banks	Banks	Banks
	Insurance	Nonlife Insurance	Full Line Insurance Insurance Brokers Property & Casualty Insurance Reinsurance
		Life Insurance	Life Insurance
	Real Estate	Real Estate Investment & Services	Real Estate Holding & Development Real Estate Services
		Real Estate Investment Trusts	Industrial & Office REITs Retail REITs Residential REITs Specialty REITs Mortgage REITs Hotel & Lodging REITs
	Financial Services	Financial Services	Asset Managers Consumer Finance Specialty Finance Investment Services Mortgage Finance
		Equity Investment Instruments	Investment companies
Technology	Technology	Software & Computer Services	Computer Services Internet Software
		Technology Hardware & Equipment	Computer Hardware Electronic Office Equipment Semiconductors Telecommunications Equipment

2.3.2 Methodology

2.3.2.1 The Fama-French Model

The FF3F model has become a widely used asset pricing model in the literature of empirical finance. In the model, two more factors are introduced, namely the size (SMB) and book-to-market (HML) factors, which are not fully captured by the CAPM's beta. Later, Carhart (1997) develops a four-factor asset pricing model by adding the momentum factor to the FF3F model. Some studies, such as Rajgopal (1999), Sadorsky (2001), and Jin and Jorion (2006), use this four-factor model and add a commodity price risk factor (e.g., the oil price risk factor).

These authors conclude that, although this model accounts for the systematic risk factors at the aggregate level, at the industry level, it may not detect commodity price risk. Mohanty et al. (2014) apply this model in order to measure the oil price sensitivity of the U.S. travel and leisure industry. Contrary to others, they demonstrate that the augmented oil price risk factor explains the subsectors' returns in the aforesaid industry.

In 2015, Fama and French have introduced a five-factor model (FF5F). They incorporate the profitability (RMW) and investment patterns (CMA) factors into the FF3F model. They assert that this new model outperforms the FF3F model in predicting stock returns. This study applies the FF5F model at the subsector level for the first time by integrating the oil price risk factor in the form of the following multifactor model:

$$R_{it} = \alpha_i + \beta_i MKT_t + \gamma_i SMB_t + \delta_i HML_t + \theta_i RMW_t + \mu_i CMA_t + \sigma_i Oil_t + \varepsilon_{it} \quad (1)$$

where R_{it} is the monthly log return on subsector i in excess of the 1-month Treasury bill rate; MKT_t is the monthly return on the market portfolio, which is calculated as the value-weighted return of all CRSP stocks incorporated in the U.S. in excess of the 1-month Treasury bill rate; SMB_t (Small Minus Big) is the monthly return of a small-cap portfolio in excess of a large-cap portfolio; HML_t (High Minus Low) is the monthly return of a portfolio with high book-to-market ratio (a value portfolio) in excess of a portfolio with low book-to-market ratio (growth portfolio); RMW_t (Robust Minus Weak) is the monthly return of a portfolio with robust operating profitability in excess of a portfolio with weak operating profitability; CMA_t (Conservative Minus Aggressive) is the monthly return of a portfolio with conservative investment in excess of a portfolio with aggressive investment; and Oil_t is the monthly return on West Texas Intermediate crude oil (WTI). For subsector i, the coefficients β_i, γ_i, δ_i, θ_i, μ_i, and σ_i quantify the market, size, book-to-market, profitability, investment patters, and oil price risk exposure, respectively. The idiosyncratic error term is ε_{it}.

Given the occurrence of some structural changes in oil and financial markets over the last three decades, the existence of structural breaks should be tested in the relationship between subsector equity returns and oil price changes. Hence, the test of Bai and Perron (2003) is employed in order to find the structural shifts in the relationship between subsector equity returns and oil price changes. This method allows testing for multiple structural breaks in a linear model and, using least squares estimation, it can detect breaks at a priori unknown dates.

Allowing for multiple breaks in the factors, the Eq. (1) can be reformulated and use the following regression model with m breaks (m + 1 regimes[1]):

$$R_{it} = \alpha_{ij} + \beta_{ij}MKT_t + \gamma_{ij}SMB_t + \delta_{ij}HML_t + \theta_{ij}RMW_t + \mu_{ij}CMA_t + \sigma_{ij}Oil_t + \varepsilon_{it} \qquad t = T_{j-1} + 1, \ldots, T_j \tag{2}$$

for j =1, …, m + 1. The breakpoints ($T_1, \ldots, T_m$) are explicitly treated as unknown, and by convention, $T_0 = 0$ and $T_{m+1} = T$ where T is the total sample size. The rest of parameters (factors) are previously described. The Bai-Perron sequential test statistics detects the number of breaks. The SupF (l +1 | l) test is a sequential test of the null hypothesis of l breaks versus the alternative of l + 1 breaks. Later, the breakpoint regression is used to estimate the multifactor model in Eq. (2) for the sub-periods based on breakpoint(s) determined by the Bai-Perron sequential test results.

2.3.2.2 Time-varying Parameter Model

To check the robustness of the results of breakpoint regressions, a time-varying parameter model is employed to examine the stability of subsector equity returns and oil price relationships. This model is in state-space form and is characterized by the following system of equations:

$$R_{it} = \alpha_{it} + \beta_{it}MKT_t + \gamma_{it}SMB_t + \delta_{it}HML_t + \theta_{it}RMW_t + \mu_{it}CMA_t + \sigma_{it}Oil_t + \varepsilon_{it} \tag{4}$$

$$\alpha_{it} = \alpha_{it-1} + \omega_{\alpha t} \tag{5}$$

$$\beta_{it} = \beta_{it-1} + \omega_{\beta t} \tag{6}$$

$$\gamma_{it} = \gamma_{it-1} + \omega_{\gamma t} \tag{7}$$

$$\delta_{it} = \delta_{it-1} + \omega_{\delta t} \tag{8}$$

$$\theta_{it} = \theta_{it-1} + \omega_{\theta t} \tag{9}$$

$$\mu_{it} = \mu_{it-1} + \omega_{\mu t} \tag{10}$$

[1] A “regime” means a period. If there is one break, there will be two regimes.

$$\sigma_{it} = \sigma_{it-1} + \omega_{\sigma t} \quad (11)$$

where $\alpha_{it,}$ $\beta_{it,}$ $\gamma_{it,}$ $\delta_{it,}$ $\theta_{it,}$ $\mu_{it,}$ and σ_{it} represent the state variables to be estimated. The disturbance terms are $\varepsilon_{it,}$ $\omega_{\alpha t,}$ $\omega_{\beta t,}$ $\omega_{\gamma t,}$ $\omega_{\delta t,}$ $\omega_{\theta t,}$ $\omega_{\mu t,}$ and $\omega_{\sigma t}$. The disturbance terms are assumed to be normally distributed with zero mean, and they are not serially correlated. In the above state-space model, Eq. (4) is the measurement equation, and Eqs. (5)–(11) are the transition equations. The maximum likelihood, along with the Kalman filter (Kalman, 1960), can be used to estimate the model parameters. The Kalman filter is a recursive process for computing the minimum mean square error (MSE) estimate of the state vectors at time *t*, using information available at time *t-1*. These estimates are updated when further information becomes available.

2.3.2.3 Time-varying Causality in Return

In order to test the return spillover between oil prices and the subsectors' returns, the causal linkages between them should be examined. The most conventional way of testing this causal relationship has been the Granger causality test in finance and economic literature. According to Brooks (2014), the concept of Granger causality (Granger, 1969, 1980) does not imply a ''causes-and-effects'' relationship between two variables. Instead, it merely indicates a "correlative" relationship among the past values of one variable and the current value of another. Hong et al. (2009) describe Granger causality as "incremental predictive ability" which can be utilized as a proper tool for inspecting and forecasting risk spillovers between different financial assets and markets. Although, this method has been used in a large body of the literature, but it is unable to capture the non-linear causal linkages (Billio et al., 2012).

Several methods have been introduced for testing causality since Granger presented the causality concept for the first time in 1969. Most of these tests use the vector autoregressive (VAR) model introduced by Sims (1972). In 1976, an asymptotically chi-squared test introduced by Haugh based on the residual cross correlations in order to check Granger causality in mean. As an extension to the work of Haugh (1976), Cheung and Ng (1996) introduce the test of causality in variance. Due to convenience of Granger-type causality tests for forecasting and causal inferences, they have been extensively adopted in finance and economics. Newly, time-varying Granger causality has gained great attention from scholars. As a result, a limited number of new tests have been introduced.

For instance, Aaltonen and Östermark (1997) propose a fixed-length rolling window Granger causality test to measure the time-varying Granger causality among the Japanese and Finnish security markets in 1990s. Moreover, a Bayesian VAR model with time-varying parameters is introduced by Cogley and Sargent (2001) to test the causal dynamics between inflation, interest rate, and unemployment in the United States.

Given the structural breaks and crises in the financial time series, non-linear causal relationships may exist due to volatility and return spillover effects. As the linear and non-linear causal relationships are dependent to the sample data, a causality framework with dynamic rolling window is employed. In this study, the Hill's (2007) fixed-length rolling window causality test will be used. He suggests a successive multi-horizon non-causality test, which can be adopted to detect non-linear causalities in terms of linear parametric restrictions for a trivariate process.

The Wald-type test statistics is used in this causality test under joint null hypothesis of zero parameter linear constraints. This time-varying causality test has a vector autoregressive (VAR) structure of order *p* at horizon h, as the following:

$$W_{t+h} = \alpha + \sum_{k=1}^{p} \pi_k^{(h)} W_{t+1-k} + u_{t+h} \tag{12}$$

where W_t is a *m*-vector process with stationarity, m ≥ 2, α is the constant term, $\pi_k^{(h)}$ are matrix-valued coefficients, and u_t is a zero mean white noise process (*m*×1 vector) with non-singular covariance matrix. This study utilizes the bivariate case where *m*=2. Therefore, the aim is to test the null hypothesis of non-causality running from oil prices (WTI) to the subsectors' returns. Causality takes place at any horizon if and only if it takes place at horizon 1 (first month in each window). W_t is a 2-vector stationary process, $W_t = \{S_t, R_t\}$ where R does not linearly causes S at 1-step ahead if and only if the RS-block $\pi_{RS,1}^{(h)} = 0$ for $k = 1$. Due to likely substandard performance of the chi-squared distribution in small samples, Hill (2007) proposed a parametric bootstrapping approach for estimating small sample *p*-values.

2.3.2.4 Time-varying Causality in Risk

In order to test the risk spillover between oil prices and the subsectors' returns, the causal linkages between them should be investigated. In this case, the same methodology of Hill's (2007) time-varying causality will be adopted. The only difference is that instead of the oil and subsectors' returns, their value-at-risks (VaR) will be used to measure the risk spillover from crude oil market to the subsectors. The main rationale to investigate the risk spillover between markets is "financial contagion" in the event of global crises, causing them to suffer from a same shock. The VaR approach is selected to measure market risk, because it illustrates market risk through the probability distribution of a random variable and estimates the risk with a single real number. Therefore, VaR has turn out to be an important tool for financial risk measurement (Fan, 2000; Tan and Chan, 2003; Hartz et al., 2006; Fan et al., 2004). The VaR approach is also appropriate for measuring the risk in oil markets, and a number of authors have done promising research using VaR (Cabedo and Moya, 2003; Feng et al., 2004; Fan et al., 2008).

The VaR can be calculated in three different ways such as the historical simulation (HS), the historical simulation with ARMA forecasts (HSAF) and the variance–covariance approach based on ARCH or autoregressive conditional heteroskedasticity family models forecasts. In this study, an ARCH-type model will be adopted to estimate the VaR model for the crude oil prices and the subsectors' returns. When using ARCH family models to estimate the VaR, most of researchers assume that residuals have standard normal or student distributions.

But indeed, the oil and stock prices usually have leptokurtic or fat-tailed distribution which is pretty different from their assumptions (Wu et al., 2012). Consequently, the developed VaR model based on these assumptions seems to be inefficient which eventually affects the risk assessment. The solution is to estimate the ARCH-type models based on generalized error distribution (GED) which provides a comprehensive distribution (Nelson, 1990). Furthermore, the adequacy of the developed VaR model can be evaluated via a backtesting method proposed by Kupiec (1995).

2.3.2.4.1 GED-EGARCH-VaR Model

This study employs an ARCH-type model based on GED in order to capture the oil and subsectors' returns volatilities to be used in the VaR model. This is because

ARCH family models can be advantageous when there is volatility clustering. Most of financial time series are often prone to this phenomenon. Engle (1982) introduced the standard ARCH model to describe the volatility clustering. The generalized version of ARCH model known as GARCH (Bollerslev, 1986) can be utilized when the lag of ARCH models became too large. The GARCH(p, q) model can be expressed as follows:

$$r_t = x_t'\beta + \varepsilon_t$$

$$\sigma_t^2 = \omega + \sum_{i=1}^{p} \alpha_i \, \varepsilon_{t-i}^2 + \sum_{j=1}^{q} \beta_j \, \sigma_{t-j}^2 \tag{13}$$

where r_t denotes the oil price and subsectors' returns, x_t is a column vector of independent variables, β is a column vector coefficient, and σ_t^2 is conditional variance. This GARCH model can be estimated by choosing p>0 and q≥ 0 where p is the order of the moving average terms (ARCH) and q is the order of the autoregressive terms (GARCH). Empirically, it is proven that the stock and commodity prices respond asymmetrically to shocks (Cont, 2001). A negative past return affects the current volatility more considerably than a positive return. Thus, when using financial data, it is essential to use a GARCH model which recognizes the asymmetry effect. The solution is the exponential generalized autoregressive conditional heteroskedasticity (EGARCH) model which proposed by Nelson (1991).

Many researchers have applied the EGARCH model because of its characteristic (He et al., 2002; Mikosch and Rezapour, 2013; Winterberger, 2013; Racicot and Theoret, 2016). The EGARCH model can be defined as follows:

$$\log(\sigma_t^2) = \omega + \sum_{i=1}^{p} \alpha_i \left| \frac{\varepsilon_{t-i}}{\sigma_{t-i}} \right| + \sum_{j=1}^{q} \beta_j \log\left(\sigma_{t-j}^2\right) + \sum_{k=1}^{r} \gamma_k \frac{\varepsilon_{t-k}}{\sigma_{t-k}} \tag{14}$$

where ω, α, β, γ, are real numbers, and $\varepsilon_t \sim IID(0, 1)$. The EGARCH model is stationary when $|\beta| < 1$, and if ε_t derives from GED with shape parameter >1. Equation 14 adds an asymmetry term into the conditional variance (σ_t^2). The sign of ε_{t-k} determines asymmetric effect. If $\varepsilon_{t-k} > 0$, the total effect of ε_{t-k} on the $\log(\sigma_t^2)$ can be measured by $(\alpha_i + \gamma_k)\left|\frac{\varepsilon_{t-i}}{\sigma_{t-i}}\right|$, whereas if $\varepsilon_{t-k} < 0$, this effect can be measured by $(\alpha_i - \gamma_k)\left|\frac{\varepsilon_{t-i}}{\sigma_{t-i}}\right|$. Therefore, the asymmetric leverage effect which first noted by Black (1976) can be measured by the coefficient γ_k.

The leverage effect can be defined as a tendency of negative correlation between the stock price changes and their volatility. This is known as leverage effect because when the market value of the firm with debt and equity outstanding falls (stock price falls), the firm becomes more leveraged (the debt to equity ratio increases). This finding is also empirically supported by Christie (1982), Schwert (1989), and Bollerslev et al. (1994). Accordingly, the negative ε_{t-k} which can be considered as bad news, may have larger impact on volatility compared with the positive ε_{t-k}. Hence, the leverage effect (γ_k) is expected to be negative.

As it is mentioned before, because the oil price and subsectors' returns are prone to have a leptokurtic (fat-tailed) distribution, hence the assumption that residuals are normally distributed seems to miscalculate the extreme risk. For this reason, the Nelson's (1990) generalized error distribution (GED) is employed here to estimate the residuals of the EGARCH models. The GED's probability density function can be presented as follows:

$$f(\varepsilon) = \frac{k[exp(-0.5\ |\varepsilon/\lambda|^k)]}{\lambda 2^{[(k+1)/k]}\Gamma(1/k)} \quad (0 \leq k \leq \infty) \tag{15}$$

where $\lambda = \left[\frac{2^{(-2/k)}\,\Gamma(1/k)}{\Gamma(3/k)}\right]^{1/2}$, Γ(●) denotes the gamma function, and k is the degree of freedom. k also known as GED parameter which displays the fatness of the tail. Specially, k<2 indicates its tail is thicker than that of the standard normal distribution; k=2, the GED exactly follows the standard normal distribution; and k>2 suggests its tail is thinner.

The value-at-risk (VaR) is a renowned technique applied to measure the possible risk of economic losses in a portfolio of financial assets. Originally, J.P. Morgan introduced VaR in 1994 and has turn out to be a standard measure of extreme market risk (Duffie and Pan, 1997; Engle and Manganelli, 2004). Financial regulatory bodies like the Basel Committee on Banking Supervision use VaR as an important tool for determining the capital risk requirements of financial institutions to ensure that they can endure catastrophic consequences of financial crises (Hong et al., 2009).

VaR estimates the maximum amount of a portfolio's value that can be lost with a given confidence level over a given time horizon, as a result of exposure to the market risk (Hendricks, 1996 and Hilton, 2003). One can be exposed to market risk by holding a short position (upside risk) or a long position (downside risk). Statistically, VaR indicates the left or the right quantile of the distribution function. The likelihood of extreme downside market risk can be shown by left tail probabilities (Embrechts et al., 1997). Volatility does not differentiate between losses and gains. Nonetheless, financial risk is apparently linked with losses but not profits.

Hence, an optimal measure of risk should consider large adverse market movements or large losses (Hong et al., 2009). The key notion behind downside risk is that the left quantile of a return distribution implicates risk whereas the right quantile encompasses the upside gain or better investment prospects (Grootveld and Hallerbach, 1999).

In line with this concern, in this thesis, the left quantile of the oil price and subsectors' returns is used to measure the downside risk, which implies the undesirable unexpected loss. For the downside risk, VaR model can be defined as follows:

$$VaR_{m,t} = -\mu_{m,t} + z_{m,\alpha}\sqrt{\sigma^2_{m,t}} \qquad (m = 1, 2, \ldots, 109 \text{ subsectors plus WTI}) \quad (16)$$

where $\mu_{m,t}$ and $\sigma^2_{m,t}$ are conditional mean and conditional variance in market *m* at time *t*, respectively. $z_{m,\alpha}$ indicates the left α-quantile of generalized error distribution (GED) in the residuals of EGARCH model in market *m*. In order to check the reliability of VaR estimates, it is necessary to backtest their adequacy for measuring the extreme market risk. For this reason, the Kupiec's (1995) backtest technique is used here. He proposed a likelihood ratio test with the null hypothesis f=α as follows:

$$LR = 2ln[(1-f)^{T-N}f^N] - 2ln[(1-\alpha)^{T-N}\alpha^N] \quad (17)$$

where T, N, f and 1−α denote sample size, days of failure, frequency of failure (f=N/T) and confidence level. The null hypothesis assumes $LR \sim x^2(1)$, and its 95% critical value is 3.84. Given the x^2 distribution, the null hypothesis should be rejected if LR value is greater than the critical value meaning that VaR estimate is not adequate.

2.4 Data Analysis and Empirical Results

2.4.1 Descriptive Statistics and Unit Root Test

Table 2-4 present the descriptive statistics and unit root test results of financial, regressors and non-financial subsectors. The mean monthly equity returns of financial subsectors ranges from -0.0003 (Investment Companies) to 0.0134 (Real Estate Holding & Development) and for the non-financial subsectors, it ranges from -0.0003 (Gold Mining) to 0.0233 (Internet). According to the standard deviation results, oil price has the highest volatility (0.0940) among the explanatory variables (regressors), showing a high level of instability in crude oil prices.

Among the financial subsectors, Real Estate Services shows the highest standard deviation (0.1425) and Mortgage REITs and Property & casualty insurance have the lowest standard deviation (0.0539). Among the non-financial subsectors, Renewable Energy Equipment shows the highest standard deviation (0.1931) and Multiutilities has the lowest standard deviation (0.0425). Figure 6 illustrates the variation of standard deviation among these subsectors.

The conventional unit root tests like Phillips and Perron (PP) and Augmented Dickey-Fuller (ADF) do not take into account the structural breaks and for this reason they have low power to reject the null hypothesis of unit root when one or more structural breaks are present (Perron, 1989). For this reason, this study opts the Zivot and Andrews (1992) test to determine the order of integration of the variables under the presence of one structural break in each series. As it is reported in Table 2-4, all variables are stationary at level form, or they are I(0).

Table 2. Descriptive statistics and unit root test results for the financials

Subsector	Period	Mean	Median	Max.	Min.	Std. dev.	ZA stat.	Break date
Asset Managers	1983M01 - 2015M04	0.0084	0.0147	0.2795	-0.3846	0.0910	-18.03**	1999M05
Banks	1983M01 - 2015M04	0.0059	0.0104	0.2729	-0.3807	0.0664	-17.75*	2009M03
Consumer Finance	1983M01 - 2015M04	0.0093	0.0132	0.3319	-0.3436	0.0710	-17.75*	2009M04
Full Line Insurance	1983M01 - 2015M04	0.0025	0.0095	0.5216	-1.1099	0.1098	-6.87*	2009M03
Hotel & Lodging REITs	1983M01 - 2015M04	0.0069	0.0069	0.5499	-0.5491	0.0971	-9.88**	2009M04
Industrial & Office REITs	1988M10 - 2015M04	0.0042	0.0100	0.4298	-0.5676	0.0761	-8.35*	1991M02
Insurance Brokers	1983M01 - 2015M04	0.0081	0.0084	0.3022	-0.3422	0.0611	-22.47*	2000M11
Investments Companies	1997M10 - 2015M04	-0.0003	0.0145	0.3857	-0.7260	0.1113	-16.86*	2008M12
Investments Services	1983M01 - 2015M04	0.0076	0.0137	0.2864	-0.4981	0.0960	-18.60**	2000M09
Life Insurance	1983M01 - 2015M04	0.0086	0.0181	0.3922	-0.6084	0.0764	-9.20*	2009M03
Mortgage Finance	1983M01 - 2015M04	0.0037	0.0146	0.3507	-0.8154	0.1057	-14.95*	2008M11
Mortgage REITs	1997M12 - 2015M04	0.0080	0.0107	0.2091	-0.2129	0.0539	-9.86*	2009M04
Property & Casualty Insurance	1983M01 - 2015M04	0.0080	0.0107	0.2091	-0.2129	0.0539	-19.79**	2009M03
Real Estate Holding & Development	1983M01 - 2015M04	0.0134	0.0131	0.4315	-0.5480	0.0916	-17.68**	2009M04
Real Estate Services	2004M08 - 2015M04	0.0123	0.0159	0.6879	-0.7197	0.1425	-17.56**	2008M12
Reinsurance	1990M08 - 2015M04	0.0093	0.0033	0.2679	-0.1585	0.0569	-18.10**	2007M11
Residential REITs	1983M01 - 2015M04	0.0063	0.0069	0.2664	-0.3854	0.0635	-8.60*	2009M04
Retail REITs	1983M01 - 2015M04	0.0071	0.0101	0.4359	-0.5486	0.0646	-7.73*	2009M04
Speciality Finance	1983M01 - 2015M04	0.0080	0.0137	0.2062	-0.3580	0.0601	-15.07*	2009M04
Speciality REITs	1983M01 - 2015M04	0.0077	0.0104	0.2530	-0.3091	0.0615	-10.34*	1991M02

Note: This stable provides the descriptive statistics and the data time span for all variables. ZA stat. refers to the Zivot-Andrews (1992) unit root test statistics and the last column presents the corresponding break date identified by this test. *, **, *** denote 1%, 5%, and 10% level of statistical significance, respectively.

Table 3. Descriptive statistics and unit root test results for the regressors

Regressors	Period	Mean	Median	Max.	Min.	Std. dev.	ZA stat.	Break date
MKT	1983M01 - 2015M03	0.0067	0.0117	0.1247	-0.2324	0.0443	-18.58*	2009M03
SMB	1983M01 - 2015M03	0.0011	-0.0001	0.1905	-0.1526	0.0297	-12.73*	1999M04
HML	1983M01 - 2015M03	0.0031	0.0024	0.1388	-0.1002	0.0293	-8.26*	2000M09
RMW	1983M01 - 2015M03	0.0048	0.0033	0.1760	-0.0886	0.0237	-16.24*	2000M02
CMA	1983M01 - 2015M03	0.0032	0.0015	0.0893	-0.0676	0.0197	-10.72*	2000M01
Oil	1983M01 - 2015M03	0.0012	0.0080	0.3825	-0.4252	0.0940	-16.60**	2008M07

Note: See Table 2.

Table 4. Descriptive statistics and unit root test results for the non-financials

Subsector	Period	Mean	Median	Max.	Min.	Std. dev.	ZA stat.	Break date
Aerospace	1983M01 - 2015M03	0.0087	0.0133	0.1546	-0.3233	0.0610	-14.73*	2009M03
Airlines	1983M01 - 2015M03	0.0044	0.0089	0.2434	-0.3905	0.0879	-14.71*	2009M04
Alternative Electricity	1983M01 - 2012M01	-0.0002	0.0028	0.1986	-0.2064	0.0589	-10.69**	2003M03
Aluminum	1983M01 - 2015M03	0.0030	0.0064	0.4268	-0.6821	0.0998	-9.55**	2009M03
Apparel Retails	1983M01 - 2015M03	0.0119	0.0162	0.2565	-0.5696	0.0921	-13.6**	2009M02
Auto Parts	1983M01 - 2015M03	0.0047	0.0089	0.3252	-0.4450	0.0643	-11.02*	2009M03
Automobiles	1983M01 - 2015M03	0.0032	0.0009	0.5923	-0.5949	0.0938	-18.75*	2009M03
Biotechnology	1983M04 - 2015M03	0.0145	0.0152	0.3647	-0.3961	0.0968	-8.56*	2000M03
Brewers	1983M01 - 2015M03	0.0097	0.0082	0.2110	-0.1773	0.0550	-20.33**	2000M12
Broadcasting & Entertainment	1983M01 - 2015M03	0.0117	0.0117	0.2803	-0.2810	0.0791	-20.13*	2009M03
Broadline Retailers	1983M01 - 2015M03	0.0080	0.0083	0.1800	-0.3060	0.0615	-13.06**	1998M07
Building Materials & Fixtures	1983M01 - 2015M03	0.0074	0.0140	0.4326	-0.3855	0.0703	-18.51**	2009M03
Business Support Services	1983M01 - 2015M03	0.0069	0.0153	0.1346	-0.2749	0.0562	-18.46*	1998M07
Business Train. & Emp. Agencies	1991M07 - 2015M03	0.0177	0.0135	0.3666	-0.2939	0.0929	-13.15*	2009M03
Clothing & Accessories	1983M01 - 2015M03	0.0104	0.0148	0.2163	-0.3816	0.0782	-17.46*	2009M03
Coal	1983M01 - 2015M03	0.0034	0.0077	0.3891	-0.4588	0.1083	-10.14*	2008M07
Commercial Vehicles & Trucks	1983M01 - 2015M03	0.0068	0.0093	0.2790	-0.3998	0.0792	-19.52*	2008M01
Commodity Chemicals	1983M01 - 2015M03	0.0066	0.0096	0.2639	-0.3150	0.0643	-20.18*	2009M03
Computer Hardware	1983M01 - 2015M03	0.0080	0.0127	0.2319	-0.3460	0.0757	-20.09*	2000M09
Computer Services	1983M01 - 2015M03	0.0068	0.0108	0.2358	-0.2907	0.0593	-20.79**	2000M01
Consumer Electronics	1986M12 - 2015M03	0.0122	0.0159	0.4491	-0.6634	0.1370	-16.55***	2000M04
Containers & Packaging	1983M01 - 2015M03	0.0076	0.0129	0.1927	-0.3185	0.0617	-15.66*	2009M03
Conventional Electricity	1983M01 - 2015M03	0.0042	0.0072	0.1253	-0.1441	0.0425	-18.61**	2002M10
Defense	1983M01 - 2015M03	0.0068	0.0158	0.1860	-0.3464	0.0591	-9.25**	1998M03
Delivery Services	1983M01 - 2015M03	0.0058	0.0060	0.3183	-0.2377	0.0787	-11.05**	1999M06
Distillers & Vintners	1983M01 - 2015M03	0.0098	0.0092	0.2442	-0.3241	0.0658	-11.96*	2009M04
Diversified Industrials	1983M01 - 2015M03	0.0049	0.0089	0.2076	-0.3092	0.0587	-19.4*	2009M03
Drug Retailers	1983M01 - 2015M03	0.0088	0.0127	0.1798	-0.2982	0.0656	-18.33*	1999M01
Durable Household Products	1983M01 - 2015M03	0.0063	0.0071	0.3670	-0.3662	0.0726	-9.43*	2009M03
Electrical Comp. & Equipment	1983M01 - 2015M03	0.0101	0.0155	0.2367	-0.3514	0.0649	-15.22**	2000M09
Electronic Equipment	1983M01 - 2015M03	0.0079	0.0127	0.3242	-0.3212	0.0817	-18.74*	2000M03
Electronic Office Equipment	1983M01 - 2015M03	0.0056	0.0075	0.1934	-0.3537	0.0783	-21.569**	1999M02
Exploration & Production	1983M01 - 2015M03	0.0058	0.0056	0.2646	-0.2772	0.0712	-20.31**	2008M07
Farming & Fishing	2000M11 - 2015M03	0.0128	0.0129	0.2568	-0.4013	0.0915	-17.19**	2009M03
Financial Administration	1983M01 - 2015M03	0.0117	0.0130	0.2049	-0.2852	0.0560	-20.76*	2000M12
Fixed Line Telecommunications	1983M01 - 2015M03	0.0036	0.0074	0.2736	-0.2070	0.0539	-8.47*	1999M07
Food Products	1983M01 - 2015M03	0.0090	0.0095	0.1915	-0.1940	0.0445	-19.99*	2009M04
Food Retailers & Wholesalers	1983M01 - 2015M03	0.0106	0.0108	0.3177	-0.2711	0.0545	-18.82**	1999M01
Footwear	1983M01 - 2015M03	0.0114	0.0161	0.2939	-0.4631	0.0967	-14.79**	1997M03
Forestry	2008M02 - 2015M03	0.0090	0.0159	0.2204	-0.1936	0.0708	-16.89**	2009M03
Furnishings	1983M01 - 2015M03	0.0077	0.0152	0.3110	-0.3328	0.0787	-10.73*	2009M03
Gambling	1983M01 - 2015M03	0.0083	0.0130	0.6072	-0.6851	0.1107	-9.20*	2009M04
Gas Distribution	1983M01 - 2015M03	0.0053	0.0101	0.2024	-0.2154	0.0562	-12.32*	2001M01
Gold Mining	1983M01 - 2015M03	-0.0003	0.0017	0.4143	-0.8166	0.1079	-11.95*	2000M11

Note: See Table 2.

Table 4. Continued

Subsector	Period	Mean	Median	Max.	Min.	Std. dev.	ZA stat.	Break date
Health Care Providers	1983M01 - 2015M03	0.0109	0.0192	0.1891	-0.3895	0.0796	-21.94**	2006M01
Heavy Construction	1983M01 - 2015M03	0.0059	0.0061	0.4067	-0.3442	0.0822	-18.05***	2008M06
Home Construction	1983M01 - 2015M03	0.0075	0.0071	0.3507	-0.4398	0.1017	-14.68*	2005M08
Home Improvement Retail	1983M01 - 2015M03	0.0098	0.0117	0.1936	-0.3651	0.0681	-15.91*	2000M01
Hotels	1983M01 - 2015M03	0.0083	0.0123	0.4252	-0.3234	0.0864	-10.68*	2009M03
Industrial Machinery	1983M01 - 2015M03	0.0087	0.0101	0.2517	-0.3763	0.0685	-20.34**	2009M03
Industrial Suppliers	1983M01 - 2015M03	0.0092	0.0121	0.2271	-0.3542	0.0695	-20.86**	2000M10
Integrated Oil & Gas	1983M01 - 2015M03	0.0073	0.0096	0.1963	-0.1682	0.0490	-22.14**	2008M01
Internet	1992M04 - 2015M03	0.0233	0.0312	0.3679	-0.3523	0.1256	-15.59*	2000M01
Iron & Steel	1983M01 - 2015M03	0.0054	0.0108	0.2816	-0.4696	0.0958	-19.13**	2003M04
Marine Transport	1983M01 - 2015M03	0.0038	0.0143	0.2966	-0.5156	0.1040	-19.33***	1987M12
Media Agencies	1983M01 - 2015M03	0.0090	0.0102	0.3341	-0.4035	0.0741	-19.98*	2000M01
Medical Equipment	1983M01 - 2015M03	0.0096	0.0131	0.1627	-0.2546	0.0506	-18.65**	1998M08
Medical Supplies	1983M01 - 2015M03	0.0095	0.0105	0.1481	-0.1876	0.0487	-19.28***	1999M01
Mobile Telecommunications	1983M01 - 2015M03	0.0063	0.0188	0.3612	-0.4184	0.0924	-9.55*	2000M01
Multiutilities	1983M01 - 2015M03	0.0046	0.0081	0.1256	-0.1660	0.0425	-20.49*	2003M04
Nondurable Household Products	1983M01 - 2015M03	0.0081	0.0122	0.2194	-0.3842	0.0565	-20.89**	1999M04
Nonferrous Metals	1983M01 - 2015M03	0.0061	0.0088	0.3780	-0.4490	0.0967	-9.97***	2007M11
Oil Equipment Services	1983M01 - 2015M03	0.0044	0.0102	0.3086	-0.4071	0.0873	-18.56***	2008M07
Paper	1983M01 - 2015M03	0.0042	0.0075	0.5384	-0.4718	0.0851	-10.13*	2009M03
Personal Products	1983M01 - 2015M03	0.0085	0.0130	0.1965	-0.2435	0.0511	-16.17**	1998M05
Pharmaceuticals	1983M01 - 2015M03	0.0090	0.0125	0.1466	-0.1810	0.0479	-20.37*	1999M04
Pipelines	1983M01 - 2015M03	0.0068	0.0105	0.1736	-0.2665	0.0573	-10.18**	2001M05
Platinum & Precious Metals	1995M01 - 2011M07	0.0009	0.0000	0.4578	-0.5365	0.1455	-16.48*	2009M03
Publishing	1983M01 - 2015M03	0.0050	0.0040	0.1548	-0.2887	0.0530	-18.71*	2009M03
Railroads	1983M01 - 2015M03	0.0090	0.0154	0.2206	-0.3643	0.0624	-18.96**	2009M03
Recreational Products	1995M01 - 2015M03	0.0114	0.0160	0.4406	-0.3412	0.0974	-15.3**	2009M04
Recreational Services	1983M01 - 2015M03	0.0094	0.0120	0.2769	-0.3392	0.0785	-18.69*	2009M02
Renewable Energy Equipments	2006M12 - 2015M03	0.0070	0.0271	0.5464	-0.4778	0.1931	-10.00*	2012M06
Restaurants & Bars	1983M01 - 2015M03	0.0110	0.0149	0.1746	-0.1893	0.0542	-18.95**	1999M04
Semiconductors	1983M01 - 2015M03	0.0085	0.0121	0.2923	-0.4223	0.1022	-20.4*	2000M09
Soft Drinks	1983M01 - 2015M03	0.0098	0.0129	0.1738	-0.2030	0.0536	-20.25*	1998M07
Software	1983M01 - 2015M03	0.0157	0.0152	0.3579	-0.2840	0.0893	-20.74*	2000M01
Specialized Consumer Services	1983M01 - 2015M03	0.0098	0.0163	0.2354	-0.2464	0.0704	-9.23*	2005M01
Specialty Chemicals	1983M01 - 2015M03	0.0099	0.0136	0.2033	-0.3275	0.0573	-19.5**	1998M05
Specialty Retailers	1983M01 - 2015M03	0.0108	0.0133	0.2343	-0.3146	0.0695	-15.82*	2000M01
Telecommunications Equipment	1983M01 - 2015M03	0.0079	0.0156	0.2828	-0.4909	0.0896	-19.82*	2000M04
Tires	1983M01 - 2015M03	0.0013	-0.0005	0.5740	-0.5908	0.1238	-8.23**	2003M03
Tobacco	1983M01 - 2015M03	0.0109	0.0196	0.2791	-0.2886	0.0714	-19.62**	2000M03
Toys	1983M01 - 2015M03	0.0070	0.0108	0.2444	-0.5133	0.0757	-17.66**	2009M02
Transportation Services	1983M01 - 2015M03	0.0044	0.0048	0.2310	-0.5004	0.0865	-9.82***	2001M01
Travel & Tourism	1983M10 - 2015M03	0.0126	0.0152	0.4777	-0.5376	0.1215	-9.83*	2009M04
Trucking	1983M01 - 2015M03	0.0077	0.0088	0.1568	-0.3496	0.0549	-15.2***	1997M10
Waste & Disposal Services	1983M01 - 2015M03	0.0057	0.0103	0.2520	-0.4777	0.0801	-18.55**	1990M07
Water	1983M01 - 2015M03	0.0109	0.0086	0.2569	-0.1823	0.0610	-22.28***	2000M03

Note: See Table 2.

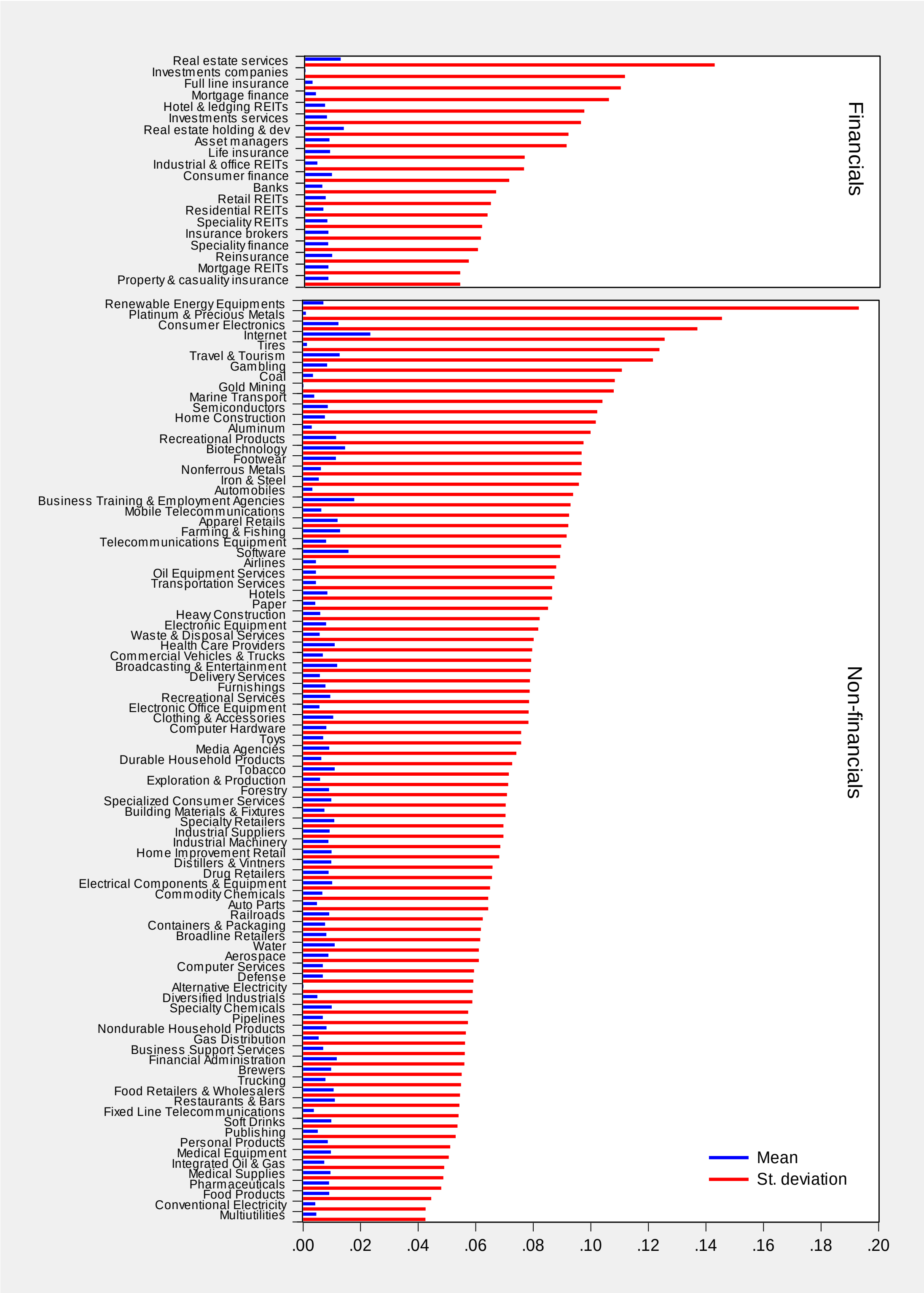


Figure 6. Ranking of the subsectors based on standard deviation

2.4.2 Testing for Structural Breaks

The Bai and Perron (2003) test results for detecting the multiple structural breaks in the relationship between subsectoral index returns and the multifactor model variables are reported in Table 5 and 6. The results of the $SupF_t$ (1 | 0) sequential test imply that most of the industries have at least one structural break at 5% statistical significance. This indicates that the assumption of constant oil price sensitivity over time is not correct, and it verifies the drawbacks of previous studies based on this assumption. In both Tables, columns five, six and seven show the number of breaks identified by the sequential approach of the Bai and Perron (2003) test and the BIC and LWZ information criteria, correspondingly.

Table 5. Multiple structural breaks in the relationship between equity returns of financial subsectors and the multifactor model variables

	$SupF_t$				Number of breaks			
Subsector	(1 | 0)	(2 | 1)	(3 | 2)	(4 | 3)	Seq.	BIC	LWZ	Break dates
Asset Managers	41.429*	19.048	-	-	1	0	0	2001M08
Banks	35.590*	32.532*	23.093	-	2	1	0	1998M09; 2007M09
Consumer Finance	40.939*	18.230	-	-	1	0	0	1991M09
Full Line Insurance	37.640*	71.564*	11.873	-	2	1	0	1998M09; 2008M02
Hotel & Lodging REITs	18.245	-	-	-	0	0	0	-
Industrial & Office REITs	26.427*	17.752	-	-	1	1	0	2004M12
Insurance Brokers	9.8045	-	-	-	0	0	0	-
Investments Companies	9.0344	-	-	-	0	0	0	-
Investments Services	27.305*	35.656*	22.532	-	2	1	1	1995M12; 2001M01
Life Insurance	28.876*	31.868*	16.245	-	2	1	0	1997M09; 2008M10
Mortgage Finance	55.898*	22.404	-	-	1	0	0	2007M11
Mortgage REITs	22.673*	15.536	-	-	1	0	0	2001M09
Property & Casualty Insurance	44.581*	25.051*	11.233	-	2	0	1	1993M04; 2001M02
Real Estate Holding & Development	22.086*	13.520	-	-	1	1	0	2006M06
Real Estate Services	13.107	-	-	-	0	0	0	-
Reinsurance	35.549*	10.525	-	-	1	0	0	1994M03
Residential REITs	27.165*	20.805	-	-	1	1	0	1988M02
Retail REITs	18.319	-	-	-	0	0	0	-
Speciality Finance	37.056*	29.258*	17.133	-	2	0	0	2003M05; 2008M11
Speciality REITs	36.031*	34.724*	27.214*	25.440	3	2	1	1989M08; 1996M04; 2009M09

Note: This table shows the test results for the endogenous structural breaks as developed by Bai and Perron (2003). Five breaks are allowed at most and the trimming parameter is 0.15. The $SupF_t$ (l +1 | l) is a sequential test of the null of *l* breaks versus the alternative of *l +1* breaks. Sequential, BIC and LWZ denote the procedure of sequentially determined breaks, Bayesian Information Criterion and Information Criterion proposed by Liu, Wu and Zidek (1997), respectively. * denotes statistical significance at 5% level.

Table 6. Multiple structural breaks in the relationship between equity returns of non-financial subsectors and the multifactor model variables

	$SupF_t$				Number of breaks			
Subsector	(1 | 0)	(2 | 1)	(3 | 2)	(4 | 3)	Seq.	BIC	LWZ	Break dates
Aerospace	24.164*	22.545	-	-	1	1	0	1998M12
Airlines	34.528*	19.529	-	-	1	0	0	2002M03
Alternative Electricity	31.877*	36.944*	28.792*	21.988	3	2	1	1987M08; 1998M10; 2007M07
Aluminum	22.382*	18.341	-	-	1	0	0	2000M01
Apparel Retailers	30.783*	23.775	-	-	1	0	0	1991M02
Auto Parts	28.325*	26.755*	7.134	-	2	2	1	1990M08; 2000M07
Automobiles	11.153	-	-	-	0	0	0	-
Biotechnology	35.364*	20.746	-	-	1	0	0	1995M12
Brewers	21.452	-	-	-	0	0	0	-
Broadcasting & Entertainment	35.508*	6.373	-	-	1	0	0	1991M02
Broadline Retailers	55.183*	29.601*	17.023	-	2	2	1	2003M04; 2009M02
Building Materials & Fixtures	53.809*	19.748	-	-	1	0	0	1987M12
Business Support Services	19.208	-	-	-	0	0	0	-
Business Train. & Emp. Agencies	31.660*	56.257*	27.000*	0.000	3	2	1	1997M08; 2001M04; 2010M02
Clothing & Accessories	23.724*	31.008*	17.775	-	2	1	0	1993M08; 2001M02
Coal	44.053*	16.092	-	-	1	0	0	2001M05
Commercial Vehicles & Trucks	36.903*	29.044*	16.301	-	2	0	0	1995M08; 2002M10
Commodity Chemicals	23.523*	18.338	-	-	1	0	0	2003M08
Computer hardware	36.601*	43.782*	28.607*	10.584	3	1	0	1993M05; 2000M08; 2010M05
Computer Services	42.399*	13.033	-	-	1	0	0	1997M07
Consumer electronics	20.712	-	-	-	0	0	0	-
Containers & Packaging	19.118	-	-	-	0	0	0	-
Conventional Electricity	24.501*	55.688*	22.770*	-	2	0	0	1995M12; 2007M04
Defense	48.956*	26.116*	24.369	-	2	1	0	1998M03; 2003M01
Delivery Services	10.129	-	-	-	0	0	0	-
Distillers & Vintners	15.502	-	-	-	0	0	0	-
Diversified Industrials	31.416*	20.602	-	-	1	0	0	2008M04
Drug Retailers	22.216*	14.649	-	-	1	0	0	2004M07
Durable Household Products	16.908	-	-	-	0	0	0	-
Electrical Comp. & Equipment	36.083*	17.965	-	-	1	0	0	2001M01
Electronic Equipment	36.820*	20.544	-	-	1	0	0	2002M08
Electronic Office Equipment	21.398	-	-	-	0	0	0	-
Exploration & Production	31.790*	18.817	-	-	1	0	0	2001M10
Farming & Fishing	27.613*	50.646*	16.062	-	2	1	0	2006M06; 2009M05
Financial Administration	22.158*	18.466	-	-	1	0	0	2001M09
Fixed Line Telecommunications	40.316*	15.511	-	-	1	0	0	1990M11
Food Products	44.033*	20.755	-	-	1	0	0	1996M10
Food Retailers & Wholesalers	27.195*	20.0252	-	-	1	1	0	1996M11
Footwear	23.711*	9.428	-	-	1	0	0	1998M11
Forestry	43.145*	18.215	-	-	1	0	0	2009M02
Furnishings	23.075*	22.772	-	-	1	1	0	2008M02
Gambling	23.379*	21.736	-	-	1	0	0	1998M02
Gas Distribution	20.112	-	-	-	0	0	0	-
Gold Mining	41.498*	14.221	-	-	1	0	0	1998M10

Note: See Table 5.

Table 6. Continued

	$SupF_t$				Number of breaks			
Subsector	(1 | 0)	(2 | 1)	(3 | 2)	(4 | 3)	Seq.	BIC	LWZ	Break dates
Health Care Providers	21.396	-	-	-	0	0	0	-
Heavy Construction	55.688*	24.262*	20.284	-	2	1	0	2001M01; 2008M12
Home Construction	34.203*	18.136	-	-	1	0	0	1994M06
Home Improvement Retail	10.169	-	-	-	0	0	0	-
Hotels	15.194	-	-	-	0	0	0	-
Industrial Machinery	35.488*	36.949*	14.487	-	2	2	0	1991M02; 2001M01
Industrial Suppliers	15.856	-	-	-	0	0	0	-
Integrated Oil & Gas	23.186*	39.861*	13.705	-	2	0	0	2002M11; 2008M05
Internet	44.842*	16.589	-	-	1	1	0	1999M03
Iron & Steel	12.142	-	-	-	0	0	0	-
Marine Transport	16.096	-	-	-	0	0	0	-
Media Agencies	15.096	-	-	-	0	0	0	-
Medical Equipment	70.275*	40.916*	16.572	-	2	1	0	1998M08; 2008M10
Medical Supplies	59.604*	32.285*	24.455	-	2	0	0	1997M01; 2002M05
Mobile Telecommunications	21.718	-	-	-	0	0	0	-
Multiutilities	29.400*	15.356	-	-	1	0	0	1988M02
Nondurable Household Products	14.334	-	-	-	0	0	0	-
Nonferrous Metals	40.749*	26.029*	16.601	-	2	0	1	1988M02; 2004M12
Oil Equipment Services	18.981	-	-	-	0	0	0	-
Paper	49.847*	19.924	-	-	1	0	0	2008M05
Personal Products	33.734*	13.432	-	-	1	0	0	2000M08
Pharmaceuticals	31.910*	15.086	-	-	1	0	0	1998M07
Pipelines	16.474	-	-	-	0	0	0	-
Platinum & Precious Metals	16.865	-	-	-	0	0	0	-
Publishing	41.952*	35.069*	13.529	-	2	1	0	1989M05; 2004M05
Railroads	32.571*	37.206*	14.738	-	2	1	1	1996M07; 2001M06
Recreational Products	18.811	-	-	-	0	0	0	-
Recreational Services	9.286	-	-	-	0	0	0	-
Renewable Energy Equipments	31.479*	19.667	-	-	1	1	0	2009M02
Restaurants & Bars	11.754	-	-	-	0	0	0	-
Semiconductors	20.657	-	-	-	0	0	0	-
Soft Drinks	36.172*	22.623	-	-	1	0	0	1999M11
Software	24.180*	65.925*	20.182	-	2	0	0	1988M01; 2002M07
Speciality Chemicals	47.099*	47.909*	14.386	-	2	1	0	1996M11; 2005M11
Specialized Consumer Services	13.921	-	-	-	0	0	0	-
Specialty Retailers	8.928	-	-	-	0	0	0	-
Telecomm equipment	24.719*	18.322	-	-	1	0	0	2000M12
Tires	32.759*	14.819	-	-	0	0	0	2004M11
Tobacco	15.741	-	-	-	0	0	0	-
Toys	32.324*	22.171	-	-	1	0	0	1991M06
Transportation services	24.460*	25.432*	9.813	-	2	2	1	1989M01; 2000M12
Travel & Tourism	21.388	-	-	-	0	0	0	-
Trucking	37.570*	17.686	-	-	1	1	0	1995M04
Waste & Disposal Services	28.977*	22.111	-	-	1	0	0	2000M01
Water	27.802*	28.605*	33.201*	10.598	3	2	1	1991M05; 1999M01; 2005M10

Note: See Table 5.

Using the Monte Carlo approach, Bai and Perron (2003, 2006) show that the information criteria do not perform well relative to the sequential procedure in detecting breaks. Consequently, we use the sequential approach for determining the number of structural breaks, and the last column in Table 5 and 6 provide the estimated break dates detected by this approach.

Although the estimated breakpoints are not exactly identical for all subsectors, there are some common break dates that can be justified through historical and economic milestones. The first series of structural shifts, occurs between 1988 and 1989, and shared by subsectors such as Nonferrous Metals, Residential REITs, and Specialty REITs. These breaks may be due to the increase in crude oil production as a result of the end of the eight-year Iran-Iraq war in 1988. Two other major milestones are the fall of Communism in Eastern Europe and the German reunification in 1989.

The second cluster of breakpoints, shared by subsectors such as Consumer Finance and Property & Casualty Insurance, occurs between 1990 and 1993. These structural breaks may be due to the effects of the U.S. recession in the early 1990s and the 1990 oil price shock resulting from Iraq's invasion of Kuwait. The third cluster of breakpoints, which are common among subsectors such as Banks, Full Line Insurance, Life Insurance, Business Training & Employment Agencies, and Gold Mining, occurs between early 1997 and late 1998. These structural changes might be linked to the effects of the Asian financial crisis in 1997, the collapse of Long-Term Capital Management (LTCM), and the Russian financial crisis in 1998.

The largest number of breaks shared by several subsectors, namely Asset Managers, Investments Services, Mortgage REITs, Property & Casualty Insurance, Airlines, Business Training & Employment Agencies, Coal, Exploration & Production, Heavy Construction, Integrated Oil & Gas, and Internet, occurs between late 1999 and late 2002. During this period, the U.S. economy witnessed some milestones, including the burst of dot-com bubble, the 9/11 terrorist attacks, and the scandals of Enron, Tyco, and WorldCom. The next round of structural shifts (2003–2006) may be triggered by the U.S. invasion of Iraq in 2003 and tremendous damages inflicted by Hurricane Katrina in 2005, the latter of which was the costliest catastrophe in the history of the U.S. insurance market (Insurance Information Institute, 2015). Moreover, the price of oil had increased from $26 in May 2003 to $60 in September 2005.

These breaks are shared by subsectors such as Industrial & Office REITs, Real Estate Holding & Development, Specialty Finance, and Nonferrous Metals. The next cluster of breaks happens during the period 2007–2009 as a result of the collapse in the U.S. subprime mortgage market, leading to a contiguous global financial crisis. Specifically, the burst of the U.S. housing bubble in late 2007 triggered the stock market failure of various industries. As shown in Table 5 and 6, these breaks occur in many subsectors, such as Banks, Full Line Insurance, Life Insurance, Mortgage Finance, Specialty Finance, Specialty REITs, Furnishings, Heavy Construction, Integrated Oil & Gas, and Renewable Energy Equipment. This cluster of breakpoints captures and demonstrates the significance of this crisis. Figure 7 illustrates the frequency of detected breakpoints for both financial and non-financial subsectors. For the sake of comparability, the 20 most sensitive non-financial subsectors along with all the financial subsectors are shown here. The 20 most sensitive non-financial subsectors are selected based on the weighted-average exposures (WAE) of their statistically significant oil coefficients in the breakpoint regressions. As shown in Figure 7, most of the structural changes occur in 2001 and 2008. This indicates that majority of structural shifts in the stock returns of these subsectors are mainly caused by the early 2000s recession in the U.S. and the 2008 U.S. subprime mortgage crisis and its spillover to the rest of the world.

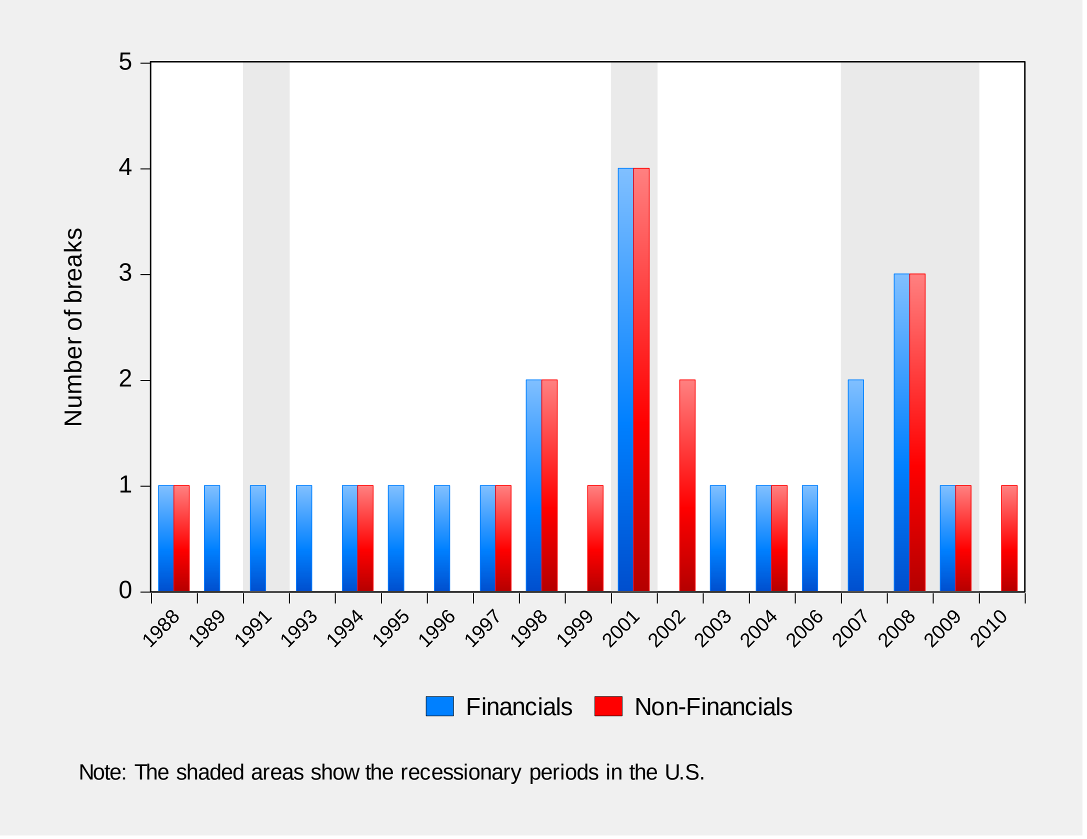


Figure 7. Frequency of structural breaks in equity returns of subsectors (January 1983 to March 2015)

Interestingly, during the period 2001–2002, non-financial subsectors had six breaks while financial subsectors had four breaks. During the period of 2007–2008, financial subsectors had five breaks while non-financial subsectors had three breaks. The recession periods are highlighted in gray.

This figure shows that non-financial subsectors are affected more by the 2001–2002 recession while financial subsectors are affected more by the 2007–2008 financial crisis. Amid these crises, the price of crude oil reached its highest level ever ($147 per barrel) in July 2008, fueling the global financial turmoil. During the next five months, oil lost almost 80% of its value. This was a result of the great plummet in oil demand due to the sudden deterioration in global economic activities and the substantial cutback of speculative positions from crude oil futures contracts (Moya-Martinez et al., 2014). The last cluster of breakpoints emerges in 2010. This is attributable to the European sovereign debt crisis, the U.S. Flash Crash of 2010, a trillion-dollar stock market crash, and the onset of the Arab Spring across the Middle East, which raised concerns about the oil supply.

2.4.3 Regression Results

Due to the existence of multiple structural breaks, Eq. (2) is estimated for the sub-periods based on the breakpoint(s) identified by the Bai-Perron sequential test. Results of the breakpoint regressions are presented in Table 7 and 8. Table 7 shows the results for the financial subsectors, and Table 8 shows the results for the non-financial sectors. Based on the results, the adjusted R2 values for the financial subsectors vary between 0.207 (Mortgage REITs) and 0.761 (Banks) and, for the non-financial subsectors, between 0.223 (Gold Mining) and 0.751 (Electrical Component & Equipment). The results in both tables show that the market risk premium (MKT) is a key factor in determining the stock returns across all financial and non-financial subsectors, and its coefficient is statistically significant and positive for all subsectors.

Table 7. Estimation results of the multifactor model for the financials

Subsector	Breaks	Sub-samples	C	MKT	SMB	HML	RMW	CMA	Oil	Adj. R^2	DW
Asset Managers	1	1983M02 - 2001M07	0.000	1.682*	0.256	0.447	-0.170	-0.746***	-0.128**	0.662	2.064
		2001M08 - 2015M03	-0.001	1.297*	-0.020	0.200	-0.284**	0.217	0.048***		
Banks	2	1983M02 - 1998M08	-0.001	1.182*	0.184**	1.108*	0.380*	-0.885*	-0.004	0.761	2.037
		1998M09 - 2007M08	0.000	0.991*	-0.303**	0.525*	0.056	-0.018	-0.058		
		2007M09 - 2015M03	-0.007	1.185*	-0.253	1.933*	-0.608	-0.729	-0.121***		
Consumer Finance	1	1983M02 - 1991M08	0.008***	1.444*	0.046	0.673*	-1.181*	-1.102*	-0.004	0.672	2.224
		1991M09 - 2015M03	-0.001	1.324*	-0.178***	0.371**	0.283**	0.127	-0.001		
Full Line Insurance	2	1983M02 - 1998M08	0.009*	0.992*	-0.425*	0.359**	-0.789*	-0.638**	-0.058**	0.605	1.774
		1998M09 - 2008M01	0.000	0.834*	-0.363**	0.236***	0.200	0.309**	-0.111*		
		2008M02 - 2015M03	-0.032***	3.071*	-1.728**	0.927	-2.296**	-1.437	-0.121		
Hotel & Lodging REITs	0	1983M01 - 2015M03	-0.008**	1.439*	0.891*	1.044*	0.466**	-0.136	-0.063	0.486	2.110
Industrial & Office REITs	1	1988M09 - 2004M11	0.004	0.320**	0.460*	0.945*	-0.411**	-0.336	-0.014	0.438	2.024
		2004M12 - 2015M03	-0.006	1.369*	0.316	1.070*	-0.389	-1.369***	-0.109		
Insurance Brokers	0	1983M01 - 2015M03	0.001	0.905*	-0.309*	0.322**	0.215	-0.180	-0.062**	0.404	2.290
Investments Companies	0	1997M10 - 2015M03	-0.009	1.309*	0.594**	1.194**	-0.350	-0.418	0.031	0.459	2.257
Investments Services	2	1983M02 - 1995M11	0.005	1.818*	0.137	-0.022	-1.617*	-0.734	0.020	0.705	1.968
		1995M12 - 2000M12	0.012	1.867*	-0.161	0.182	-0.380	-0.015	-0.317**		
		2001M01 - 2015M03	-0.003	1.378*	-0.134	-0.020	-0.507*	-0.422**	0.043		
Life Insurance	2	1983M02 - 1997M08	0.006***	1.099*	-0.084	0.518**	-0.460**	-0.529***	-0.084**	0.741	2.125
		1997M09 - 2008M09	0.002	1.051*	-0.235**	0.567*	0.321**	0.106	-0.052		
		2008M10 - 2015M03	-0.014***	1.979*	-0.076	1.472*	-0.327	-1.513***	-0.070		
Mortgage Finance	1	1983M02 - 2007M10	-0.003	1.368*	0.010	0.397	0.798*	0.365	-0.143*	0.382	1.606
		2007M11 - 2015M03	-0.037*	2.107*	-1.066**	-2.268*	-1.228***	1.535***	-0.225**		
Mortgage REITs	1	1997M11 - 2001M08	0.013	0.279	0.922*	1.763*	-0.357	-2.016*	0.044	0.207	1.996
		2001M09 - 2015M03	-0.005	0.478*	-0.106	0.155	0.097	0.394	0.029		
Property & Casualty Insurance	2	1983M02 - 1993M03	0.013*	0.879*	-0.213	0.358***	-0.852*	-0.959*	-0.021	0.654	2.294
		1993M04 - 2001M01	-0.008***	1.281*	-0.179	1.042*	0.354***	0.260	-0.037		
		2001M02 - 2015M03	-0.001	0.848*	0.063	0.338*	0.126	0.276	-0.055***		
Real Estate Holding & Development	1	1983M02 - 2006M05	0.006	0.983*	0.138	0.809*	0.133	-0.081	-0.028	0.367	2.107
		2006M06 - 2015M03	-0.003	1.439*	0.771**	0.491	0.095	-1.214	0.135		
Real Estate Services	0	2004M08 - 2015M03	0.001	1.788*	0.739***	0.849**	-0.711	-1.209	0.203**	0.586	2.150
Reinsurance	1	1990M07 - 1994M02	0.009	1.091*	-0.053	0.194	-0.694	-1.738	0.042	0.334	2.107
		1994M03 - 2015M03	0.006***	0.543*	-0.284**	0.456*	-0.271***	0.216	-0.035		
Residential REITs	1	1983M02 - 1988M01	0.018***	0.322***	1.302***	0.000	-0.288	-0.921	0.261***	0.375	2.161
		1988M02 - 2015M03	-0.001	0.745*	0.434*	0.776*	0.097	-0.076	-0.021		
Retail REITs	0	1983M01 - 2015M03	-0.001	0.802*	0.506*	0.916*	0.090	-0.191	0.003	0.400	2.248
Specialty Finance	2	1983M02 - 2003M04	0.001	1.000*	0.061	0.247**	0.364*	0.022	-0.032	0.665	2.270
		2003M05 - 2008M10	-0.012	1.855*	0.217	0.925***	0.137	-0.352	-0.126***		
		2008M11 - 2015M03	-0.002	1.216*	-0.197	-0.242	-0.366	-0.131	-0.026		
Specialty REITs	3	1983M02 - 1989M07	0.007***	0.952*	0.230	-0.457**	0.521	0.101	-0.085**	0.595	2.294
		1989M08 - 1996M03	-0.003	1.437*	0.704*	0.496	-0.136	0.209	-0.151***		
		1996M04 - 2009M08	-0.003	0.734*	0.557*	0.832*	0.021	-0.084	-0.031		
		2009M09 - 2015M03	0.000	0.751*	-0.415	-0.229	-0.379	0.393	-0.043		

Note: This table reports the breakpoint regression results of the multifactor linear model in Eq. (2) for the financial subsectors and sub-samples based on the breakpoints identified by the test of Bai and Perron (2003). Standard errors of the estimated coefficients are corrected for heteroscedasticity by the White procedure. Breaks denote the number of breaks selected by the sequential procedure of Bai and Perron (2003) at 5% statistical significance level. *, **, and *** denote statistical significance at the 1%, 5% and 10% levels, respectively.

Table 8. Estimation results of the multifactor model for the non-financials

Subsector	Breaks	Sub-samples	C	MKT	SMB	HML	RMW	CMA	Oil	Adj. R^2	DW
Aerospace	1	1983M01 - 1998M11	-0.001	1.077*	0.162	-0.096	0.260	0.249	-0.069*	0.6152	2.116
		1998M12 - 2015M03	-0.001	1.095*	-0.107	0.524*	0.388**	0.125	0.058***		
Airlines	1	1983M01 - 2002M02	-0.008***	1.338*	0.319**	0.782*	0.518**	-0.55	-0.038***	0.471	1.967
		2002M03 - 2015M03	-0.003	1.105*	0.501***	0.646**	-0.293	-0.449	-0.466*		
Alternative Electricity	3	1983M01 - 1987M07	-0.007	0.832*	-0.531	1.526*	0.121	-1.785*	-0.027**	0.433	2.064
		1987M08 - 1998M09	0.001	0.489*	-0.529*	0.186	-0.534**	0.262	-0.063***		
		1998M10 - 2007M06	-0.008	0.704*	-0.224	1.479*	-0.633*	0.178	-0.055		
		2007M07 - 2012M01	-0.014	0.751*	0.231	0.211	-0.079	-1.353**	-0.080**		
Aluminum	1	1983M01 - 1999M12	0.006	1.006*	0.313	0.188	-0.785**	-0.384	0.074	0.493	2.195
		2000M01 - 2015M03	-0.021	1.979*	0.265	0.306	0.671***	0.287	0.136**		
Apparel Retailers	1	1983M01 - 1991M01	0.015***	1.756*	1.229*	0.385	0.951	-1.487**	0.053	0.542	2.019
		1991M02 - 2015M03	0.001	1.107*	0.397**	0.124	0.491**	-0.518	-0.066		
Auto Parts	2	1983M01 - 1990M07	-0.001	0.973*	0.107	-0.153	-0.285	0.699***	-0.057**	0.672	2.037
		1990M08 - 2000M06	-0.009*	0.977*	0.397*	1.090*	0.257	-0.171	-0.053		
		2000M07 - 2015M03	-0.005	1.408*	0.496*	0.153	0.633*	-0.047	0.081**		
Automobiles	0	1983M01 - 2015M03	-0.008**	1.471*	0.163	1.114*	-0.151	-0.375	-0.011	0.495	2.157
Biotechnology	1	1983M04 - 1995M11	0.024	1.100*	0.203	-1.322	-1.964	-1.295	0.077	0.469	1.932
		1995M12 - 2015M03	0.015	0.532	0.095	-0.836**	-0.819*	0.379	-0.015		
Broadcasting & Entertainment	1	1983M01 - 1991M01	0.011	1.108*	0.676**	0.568	1.171**	-1.399	-0.001	0.472	2.184
		1991M02 - 2015M03	0.004	1.009*	-0.001	0.089	-0.522**	0.172**	-0.046**		
Brewers	0	1983M01 - 2015M03	0.001	0.756*	-0.032	-0.053	0.838*	0.384***	-0.026	0.313	2.022
Broadline Retailers	2	1983M01 - 2003M03	-0.003	1.161*	0.477*	0.19	0.620*	0.189	-0.121*	0.542	2.109
		2003M04 - 2009M01	-0.001	0.914*	0.702*	-0.162	1.354*	1.079*	0.09**		
		2009M02 - 2015M03	-0.001	0.837*	-0.217	-0.617**	0.527**	0.619***	-0.104***		
Building Materials & Fixtures	1	1983M01 - 1987M11	0.002	1.276*	-0.125	-0.124	0.725	-0.018	-0.069	0.629	2.058
		1987M12 - 2015M03	-0.006**	1.205*	0.507*	0.820*	0.525*	-0.032	-0.056***		
Business Support Services	0	1983M01 - 2015M03	-0.001	1.021*	0.324*	-0.20**	0.265**	0.121	-0.011	0.699	2.103
Business Train. & Emp. Agencies	3	1991M07 - 1997M07	0.033*	0.747**	1.527*	0.267	0.136	0.133	0.638*	0.475	2.031
		1997M08 - 2001M03	0.006	1.199*	-0.661**	1.046	-0.57	0.224	-0.203		
		2001M04 - 2010M01	-0.009	1.013*	1.219*	0.19	1.082*	0.343	0.019		
		2010M02 - 2015M03	-0.013	1.741*	-0.219	-1.065**	-1.834*	0.193	-0.113		
Clothing & Accessories	2	1983M01 - 1993M07	0.005	1.374*	0.296	-0.558***	0.389	0.162	-0.103***	0.635	2.052
		1993M08 - 2001M01	0.002	0.938*	0.242	1.159*	0.742*	-1.125**	-0.063		
		2001M02 - 2015M03	-0.003	1.363*	0.464*	0.013	0.761*	-0.274	0.002		

Note: See Table 7.

Table 8. Continued

Subsector	Breaks	Sub-samples	C	MKT	SMB	HML	RMW	CMA	Oil	Adj. R^2	DW
Coal	1	1983M01 - 2001M04	-0.012**	1.324*	0.914*	0.205	0.963*	1.183**	-0.029	0.414	1.983
		2001M05 - 2015M03	-0.007	1.236*	0.416	-0.122	-0.031	-0.809	0.500*		
Commercial Vehicles & Trucks	2	1983M01 - 1995M07	0.002	1.259*	0.624*	-0.019	-1.210*	0.311	-0.025	0.645	2.028
		1995M08 - 2002M09	-0.011	1.264*	0.286***	0.850*	0.614**	-0.079	0.108**		
		2002M10 - 2015M03	-0.004	1.597*	0.446**	-0.151	0.172	-0.154	0.109**		
Commodity Chemicals	1	1983M01 - 2003M07	-0.005	1.190*	0.092	0.169	0.376**	0.596*	-0.029	0.641	2.19
		2003M08 - 2015M03	-0.004	1.356*	-0.105	0.365***	0.042	-0.583**	0.037		
Computer Hardware	3	1983M01 - 1993M04	-0.004	0.843*	0.197	-0.010	0.019	-0.388	0.031	0.689	2.265
		1993M05 - 2000M07	0.017*	0.606*	0.127	-0.804**	0.733**	-0.574	-0.036		
		2000M08 - 2010M04	0.008***	1.387*	0.175	-0.883*	-0.382***	-0.132	0.048		
		2010M05 - 2015M03	-0.005	1.364*	-0.476	-0.348	1.047*	-0.640	-0.030		
Computer Services	1	1983M01 - 1997M06	0.005	0.962*	0.466*	-0.353**	-0.156	-0.422***	0.011	0.648	2.29
		1997M07 - 2015M03	-0.001	0.950*	-0.126	-0.458*	0.093	0.544**	0.052**		
Consumer electronics	0	1983M12 - 2015M03	0.005	1.405*	0.920*	-0.091	-0.708**	-0.114	0.025*	0.388	2.046
Containers & Packaging	0	1983M01 - 2015M03	-0.002	1.144*	0.253*	0.175	0.405*	0.231	-0.026	0.611	2.032
Conventional Electricity	2	1983M01 - 1995M11	0.001	0.547*	-0.686*	0.704*	-0.378**	-0.754*	-0.041**	0.438	2.113
		1995M12 - 2007M03	-0.001	0.582*	-0.034	1.064*	-0.461*	-0.043*	0.009**		
		2007M04 - 2015M03	-0.003	0.601*	-0.394***	-0.331	-0.364	0.522***	-0.007		
Defense	2	1983M01 - 1998M02	0.004	0.845*	0.117	0.151	-0.148	-0.361	0.040	0.456	2.024
		1998M03 - 2002M12	-0.017	0.871*	0.128	0.773***	0.618**	0.294	0.211**		
		2003M01 - 2015M03	0.003	0.874*	-0.086	0.238	-0.279	-0.374	-0.023		
Delivery Services	0	1983M01 - 2015M03	-0.003	0.895*	0.378*	0.1321	0.596*	0.022	-0.063**	0.249	1.961
Distillers & Vintners	0	1983M01 - 2015M03	-0.002	0.964*	0.078	0.061	0.911*	0.374***	-0.019	0.348	2.171
Diversified Industrials	1	1983M01 - 2008M03	0.000	0.911*	-0.151	-0.018	0.102	0.136	-0.029	0.655	2.286
		2008M04 - 2015M03	-0.012*	1.421*	-0.164	0.418**	-0.070	0.640***	-0.072**		
Drug Retailers	1	1983M01 - 2004M06	-0.002	0.799*	0.275	-0.263	1.148*	0.348	-0.042	0.375	1.875
		2004M07 - 2015M03	0.004	0.941*	0.015	-0.495***	-0.609	0.924*	-0.074**		
Durable Household Products	0	1983M01 - 2015M03	-0.007	1.422*	0.446*	0.478*	0.576*	0.188	-0.059**	0.694	2.207
Electrical Comp. & Equipment	1	1983M01 - 2000M12	0.003	1.090*	-0.277*	-0.208	0.254***	0.133	-0.039	0.751	2.226
		2001M01 - 2015M03	-0.002	1.324*	0.289*	-0.191	0.040	0.097	0.075**		
Electronic Equipment	1	1983M01 - 2002M07	0.012*	1.115*	0.110	-0.373***	-1.173*	-0.252	-0.041	0.740	2.182
		2002M08 - 2015M03	-0.003	1.103*	0.365*	-0.770*	-0.239***	0.922*	0.105*		
Electronic Office Equipment	0	1983M01 - 2015M03	-0.005	1.084*	0.374**	0.011	0.363	0.386	-0.061	0.353	2.032
Exploration & Production	1	1983M01 - 2001M09	-0.010*	1.191*	0.041	0.850*	0.172	0.289	0.317*	0.573	2.1
		2001M10 - 2015M03	0.001	0.873*	0.310***	0.18	0.343	-0.690**	0.367*		

Note: See Table 7.

Table 8. Continued

Subsector	Breaks	Sub-samples	C	MKT	SMB	HML	RMW	CMA	Oil	Adj. R^2	DW
Farming & Fishing	2	2000M11 - 2006M05	0.008	1.112**	0.374	1.676*	-0.654	-0.683	-0.158	0.409	2.159
		2006M06 - 2009M04	0.036	0.327	-1.026**	-0.158	-1.581***	0.231	0.299*		
		2009M05 - 2015M03	-0.020*	1.749*	-0.604	0.110	-0.049	-0.376	-0.287*		
Financial Administration	1	1983M01 - 2001M08	0.007	0.865*	0.037	-0.129	0.675*	-0.177	0.073**	0.605	2.254
		2001M09 - 2015M03	0.000	1.065*	-0.096	-0.293***	0.073	-0.041	0.022		
Fixed Line Telecommunications	1	1983M01 - 1990M10	-0.002	0.855*	-0.550*	0.756*	0.800*	-0.686**	0.063**	0.483	2.219
		1990M11 - 2015M03	-0.003	0.852*	-0.505*	-0.222	-0.146	0.413***	-0.040		
Food Products	1	1983M01 - 1996M09	0.001	0.923*	-0.355*	-0.462*	0.706*	0.848*	-0.063**	0.550	2.153
		1996M10 - 2015M03	-0.001	0.627*	-0.089	0.176	0.517*	0.255***	0.008		
Food Retailers & Wholesalers	1	1983M01 - 1996M10	-0.001	1.028*	0.349*	-0.215	0.891*	0.378	-0.051	0.484	1.974
		1996M11 - 2015M03	0.002	0.746*	-0.056	-0.059	0.563*	0.579*	0.001		
Footwear	1	1983M01 - 1998M10	-0.003	1.353*	0.802*	-0.823***	0.824	1.281***	-0.109**	0.334	2.046
		1998M11 - 2015M03	0.007	0.896*	-0.168	0.438***	0.611**	-0.333	-0.044		
Forestry	1	2008M02 - 2009M01	-0.033	-0.697	0.679	-0.910	-1.635	-3.606***	0.193***	0.541	1.968
		2009M02 - 2015M03	0.002	0.918*	0.078	0.172	0.164	0.104	-0.156***		
Furnishings	1	1983M01 – 2008M01	-0.006**	1.308*	0.544*	0.373**	0.779*	0.202	-0.099*	0.658	2.145
		2008M02 – 2015M03	-0.007	1.588*	1.153*	0.740*	0.632	-0.915***	-0.154**		
Gambling	1	1983M01 - 1998M01	0.008	1.276*	0.982*	-0.381	0.218	-0.285	-0.005	0.505	2.026
		1998M02 - 2015M03	-0.012	1.680*	0.447	1.135*	0.449	-0.484	0.154***		
Gas Distribution	0	1983M01 - 2015M03	0.000	0.792*	-0.197***	0.327*	-0.295**	0.161	0.126*	0.441	2.011
Gold Mining	1	1983M01 - 1998M09	0.004	1.135**	0.463	-0.733***	-2.858*	1.564***	0.045	0.223	2.176
		1998M10 - 2015M03	-0.005	0.104	0.249	0.251	0.38	-0.242	0.281*		
Health Care Providers	0	1983M01 - 2015M03	0.000	1.024*	0.402*	-0.093	0.740*	0.202	0.004	0.307	1.99
Heavy Construction	2	1983M01 - 2000M12	-0.010*	1.285*	0.619*	0.397***	0.854*	0.669***	-0.075	0.577	1.944
		2001M01 - 2008M11	0.004	1.452*	0.52	-1.170*	0.904**	0.63	0.410*		
		2008M12 - 2015M03	-0.010**	0.994*	0.621**	0.088	-0.664**	-0.22	0.212*		
Home Construction	1	1983M01 - 1994M05	-0.002	1.698*	0.889*	-0.298	-0.676	-0.037	-0.196*	0.494	1.853
		1994M06 - 2015M03	-0.004	1.269*	0.542*	0.838*	0.537**	0.153	-0.121**		
Home Improvement Retail	0	1983M01 - 2015M03	-0.001	1.120*	0.145	-0.013	0.727*	0.163	-0.125*	0.494	2.019
Hotels	0	1983M01 - 2015M03	-0.003	1.357*	0.824*	0.606*	0.307***	-0.398***	-0.041**	0.573	2.007
Industrial Machinery	2	1983M01 - 1991M01	0.008	1.254*	0.573*	-0.461***	-0.685**	0.155	-0.003	0.699	2.82
		1991M02 - 2000M12	-0.005	1.141*	0.333**	0.647**	0.688*	-0.023	0.004		
		2001M01 - 2015M03	-0.003	1.348*	0.401*	-0.276**	0.589*	0.392***	0.093*		

Note: See Table 7.

Table 8. Continued

Subsector	Breaks	Sub-samples	C	MKT	SMB	HML	RMW	CMA	Oil	Adj. R^2	DW
Industrial Suppliers	0	1983M01 - 2015M03	-0.001	1.003*	0.298**	0.000	0.653*	0.289	0.012	0.359	2.175
Integrated Oil & Gas	2	1983M01 - 2002M10	-0.002	0.859*	-0.078	0.340*	0.07	0.496*	0.177*	0.572	2.096
		2002M11 - 2008M04	0.001	1.224*	-0.283	0.722***	0.053	-1.180**	0.279*		
		2008M05 - 2015M03	-0.006***	0.747*	-0.403**	-0.234	0.184	1.046*	0.136**		
Internet	1	1992M04 - 1999M02	0.074*	0.652***	0.38	-0.795	-2.135*	-3.020*	-0.464*	0.622	2.036
		1999M03 - 2015M03	0.009***	1.220*	-0.329***	-0.678*	-0.784**	-1.061*	0.05		
Iron & Steel	0	1983M01 - 2015M03	-0.007	1.501*	0.476*	0.584*	0.306	-0.198	0.091**	0.492	2.012
Marine Transport	0	1983M01 - 2015M03	-0.011**	1.331*	0.185	0.207	0.576**	0.689**	0.362*	0.371	2.070
Media Agencies	0	1983M01 - 2015M03	0.001	1.207*	0.264**	0.072	0.142	-0.099	0.033	0.549	2.043954
Medical Equipment	2	1983M01 - 1998M07	0.007*	0.889*	-0.412*	-0.894*	-0.012	0.434**	-0.033	0.664	2.163
		1998M08 - 2008M09	0.002	0.552*	-0.124	0.054	0.152	0.273	0.020		
		2008M10 - 2015M03	0.000	0.907*	-0.051	-0.393	-1.122*	-0.096	0.033		
Medical Supplies	2	1983M01 - 1996M12	0.004	0.873*	-0.418*	-0.870*	0.080	0.564***	-0.020	0.545	2.103
		1997M01 - 2002M04	0.002	0.527*	-0.257**	-0.292	0.550*	0.628**	0.019		
		2002M05 - 2015M03	0.006**	0.578*	-0.270	0.018	-0.584*	-0.592**	-0.007		
Mobile Telecommunications	0	1983M01 - 2015M03	0.006	0.924*	-0.245	-0.057	-0.800*	-0.767**	0.044	0.380	1.950
Multiutilities	1	1983M01 - 1988M01	-0.004	0.677*	-0.422***	1.401*	-0.530***	-1.301*	-0.062***	0.630	2.174
		1988M02 - 2015M03	0.002	0.444*	-0.171**	0.280*	-0.144	0.200	0.023		
Nondurable Household Products	0	1983M01 - 2015M03	0.000	0.730*	-0.124	-0.412*	0.600*	0.774*	-0.020	0.734	2.008
Nonferrous Metals	2	1983M01 - 1988M01	0.022**	0.845*	0.557	-0.887	-2.403*	0.523	-0.012	0.521	2.086
		1988M02 - 2004M11	-0.007	1.577*	0.265***	0.433***	0.197	0.43	0.118**		
		2004M12 - 2015M03	-0.008	1.690*	-0.299	-0.457	0.481	-0.835	0.399*		
Oil Equipment Services	0	1983M01 - 2015M03	-0.005	1.168*	-0.016	0.300***	0.022	-0.033	0.384*	0.521	2.118
Paper	1	1983M01 - 2008M04	-0.008**	1.176*	0.198***	0.205	0.462**	0.431**	-0.031	0.626	2.242
		2008M05 - 2015M03	-0.004	1.917*	0.141	1.731*	0.615	-1.771*	0.062		
Personal Products	1	1983M01 - 2000M07	-0.001	1.073*	-0.287**	-0.372**	0.429**	0.819*	-0.067***	0.574	2.033
		2000M08 - 2015M03	-0.001	0.693*	-0.209**	0.148	0.568*	0.435**	0.036		
Pharmaceuticals	1	1983M01 - 1998M06	0.008*	0.841*	-0.448*	-0.741*	0.058	0.473***	-0.047***	0.553	2.105
		1998M07 - 2015M03	0.001	0.639*	-0.487*	-0.105	0.013	0.417*	-0.040**		
Pipelines	0	1983M01 - 2015M03	0.002	0.737*	-0.173	0.335***	-0.284***	0.055	0.054**	0.336	2.125
Platinum & Precious Metals	0	1995M01 - 2011M07	-0.012	1.426*	0.610***	0.581	-0.102	-0.02	0.258**	0.292	2.185
Publishing	2	1983M01 - 1989M04	-0.002	1.236*	0.001	-0.418**	0.704*	0.510	-0.101*	0.726	2.258
		1989M05 - 2004M04	0.000	0.846*	0.153**	0.421*	0.228***	-0.198	-0.054***		
		2004M05 - 2015M03	-0.007*	0.996*	0.148	-0.360*	0.052	0.325	0.065***		
Recreational Products	0	1995M01 - 2015M03	-0.006	1.389*	1.146*	0.183	1.031*	0.553***	0.040	0.449	1.958

Note: See Table 7.

Table 8. Continued

Subsector	Breaks	Sub-samples	C	MKT	SMB	HML	RMW	CMA	Oil	Adj. R^2	DW
Railroads	2	1983M01 - 1996M06	0.003	1.200*	0.023	0.229	-0.508**	-0.436	0.051***	0.579	2.034
		1996M07 - 2001M05	-0.010	0.727*	0.112	1.020*	0.506	-0.432	0.093		
		2001M06 - 2015M03	0.005	1.059*	0.099	0.203	0.383***	-0.272	0.056***		
Recreational Services	0	1983M01 - 2015M03	-0.001	1.315*	0.278**	0.386***	0.061	0.093	-0.132*	0.542	2.014
Renewable Energy Equipments	1	2006M12 - 2009M01	0.097**	0.699	-1.476	-0.157	-2.821	-4.528***	0.255**	0.401	1.69
		2009M02 - 2015M03	-0.039***	2.105*	0.694	2.211**	0.178	-4.937*	-0.353		
Restaurants & Bars	0	1983M01 - 2015M03	0.002	0.927*	-0.042	-0.116	0.671*	0.361**	-0.045**	0.477	1.971
Semiconductors	0	1983M01 - 2015M03	0.002	1.396*	0.173	-0.721*	-0.237	-0.055	0.011	0.555	1.982
Soft Drinks	1	1983M01 - 1999M10	0.000	0.992*	-0.238***	-0.248	0.928*	0.778*	-0.119*	0.470	2.176
		1999M11 - 2015M03	-0.002	0.648*	-0.112	-0.252***	0.498*	0.655*	0.047		
Software	2	1983M01 - 1987M12	0.046*	1.093*	0.288	-2.438*	-1.045	0.955	0.073	0.705	2.184
		1988M01 - 2002M06	0.024*	0.693*	0.049	-0.508**	-0.023	-1.786*	-0.014		
		2002M07 - 2015M03	-0.001	1.129*	-0.096	-0.374*	-0.151	-0.164	0.005		
Specialty chemicals	2	1983M01 - 1996M10	0.003	1.111*	0.083	-0.050	-0.084	-0.101	-0.042	0.684	2.078
		1996M11 - 2005M10	-0.005	0.923*	0.044	0.662*	0.198	0.086	0.007		
		2005M11 - 2015M03	0.008***	1.045*	-0.166	-0.178	-0.084	-0.437	0.174*		
Specialized Consumer Services	0	1983M01 - 2015M03	0.003	0.990*	0.067	-0.275	0.021	0.262	-0.041	0.409	2.017
Specialty Retailers	0	1983M01 - 2015M03	0.002	1.115*	0.363*	-0.198	0.472*	-0.223	-0.095*	0.603	2.071
Telecomm equipment	1	1983M01 - 2000M11	0.001**	1.151*	0.360**	-0.527**	0.086	-0.339	-0.002	0.693	1.959
		2000M12 - 2015M03	-0.002	1.264*	-0.080	-0.756*	-1.126*	-0.145	0.010		
Tires	1	1983M01 - 2004M10	-0.018*	1.541*	0.400***	0.951*	0.227	0.084	-0.115***	0.465	1.857
		2004M11 - 2015M03	-0.003	2.029*	0.781***	0.465	-1.673**	-1.058	0.029		
Tobacco	0	1983M01 - 2015M03	-0.002	0.972*	-0.025	-0.285***	1.033*	0.923*	0.013	0.290	2.051
Toys	1	1983M01 - 1991M05	0.002	1.491*	1.050*	0.531	0.914***	-0.321	-0.049**	0.446	2.030
		1991M06 - 2015M03	-0.006	0.864*	0.352**	-0.103	0.714*	0.591**	0.077		
Transportation services	2	1983M01 - 1988M12	0.010	1.204*	0.283	-0.508	-0.300	-0.714	0.047	0.504	1.991
		1989M01 - 2000M11	-0.008	1.032*	0.413**	1.075*	0.184	-0.899***	-0.213*		
		2000M12 - 2015M03	-0.004	1.245*	0.412**	0.248	0.737**	0.379	0.206*		
Travel & Tourism	0	1983M10 - 2015M03	0.001	1.566*	0.998*	-0.271	0.598**	-0.056	0.002	0.421	2.130
Trucking	1	1983M01 - 1995M03	0.002	1.177*	0.143	0.267	-0.393***	-0.328	0.013	0.554	2.086
		1995M04 - 2015M03	0.000	0.798*	0.229**	0.272**	0.547*	-0.060	-0.010		
Waste & Disposal Services	1	1983M01 - 1999M12	-0.011***	1.415*	0.185**	0.895	0.596	-0.868	0.002	0.362	1.824
		2000M01 - 2015M03	0.001	0.633*	0.173	0.124	0.351	0.576***	-0.014		
Water	3	1983M01 - 1991M04	0.020*	0.451*	0.605**	1.004*	-0.463	-1.932*	0.160**	0.247	2.215
		1991M05 - 1998M12	0.008	0.480**	-0.361**	-0.482	-0.187	0.352	0.075		
		1999M01 - 2005M09	0.021*	-0.346	-0.028	0.768**	-0.684**	-0.215	-0.230*		
		2005M10 - 2015M03	0.000	0.565*	-0.008	-0.911*	-0.496	1.276*	-0.085		

Note: See Table 7.

Moreover, the range of coefficients is in line with the typical beta coefficients. This result is consistent with the findings of Fama and French (1993) and the others who applied this model (Mohanty and Nandha, 2011; Elyasiani et al., 2011; Mohanty et al., 2014). For the financial subsectors, MKT ranges from 0.279 (Mortgage REITs) to 3.071 (Full Line Insurance); SMB (size premium) ranges from -1.728 (Full Line Insurance) to 1.302 (Residential REITs); HML (value premium) ranges from -2.268 (Mortgage Finance) to 1.933 (Banks); RMW (profitability premium) ranges from -2.296 (Full Line Insurance) to 0.798 (Mortgage Finance); and CMA (investment strategy premium) ranges from -2.016 (Mortgage REITs) to 1.535 (Mortgage Finance).

For the non-financial subsectors, MKT ranges from -0.697 (Forestry) to 2.105 (Renewable Energy Equipment); SMB ranges from -1.476 (Renewable Energy Equipment) to 1.527 (Business Training & Employment Agencies); HML ranges from -2.438 (Software) to 2.211 (Renewable Energy Equipment); RMW ranges from -2.858 (Gold Mining) to 1.354 (Broadline Retailers); and CMA ranges from -4.937 (Renewable Energy Equipment) to 1.564 (Gold Mining).

Considering the effect of oil prices on the subsector equity returns in Table 7, 12 out of 20 financial subsectors exhibit a statistically significant exposure to the price of oil in at least one of the sub-periods, whereas for the non-financials in Table 8, all of the 20 most sensitive subsectors show a statistically significant exposure to the price of oil. It is worthwhile to mention that the magnitude and sign of oil price sensitivity varies over time and across industries.

In order to identify which subsector is more exposed to oil price risk, both financial and non-financial subsectors are ranked based on their weighted average of oil price exposures (WAE) using the following equation:

$$\mathrm{WAE}_x = \sum_{i=1}^{k} \left[SSC_i \left(\frac{SO_i}{TO_x} \right) \right] \tag{18}$$

where WAE_x refers to the weighted average of oil price exposure of *x* subsector, *k* is the maximum number of sub-samples (regimes) in the breakpoint regression, SSC_i is the statistically significant oil coefficient in the i_{th} sub-sample, SO_i is the number of observations in the i_{th} sub-sample, and TO_x is the total number observations of *x* subsector. We only take into account the statistically significant oil coefficients (SSC_i) in the breakpoint regressions and multiply each of them by the fraction of the number of observations in the corresponding sub-period over the total number of observations.

This is due to the empirical observation in our results that some subsectors have large significant oil coefficients but that these values correspond to relatively short time periods. For instance, the Business Training & Employment Agencies subsector has a significant oil coefficient of 0.638 but it only lasts for 73 months out of 284 months. Figure 8 exhibits the magnitude and sign of oil price exposure of the financial and non-financial subsectors.

For the sake of comparability, the 20 most sensitive non-financial subsectors along with all the financial subsectors are shown here. The 20 most sensitive non-financial subsectors are selected based on the WAE of their statistically significant oil coefficients in the breakpoint regressions. As is shown in Figure 8, the majority of the financial subsectors are negatively affected by oil prices.

Conversely, most of the non-financial subsectors are positively affected. Moreover, the magnitude of the impact of oil price on the financial subsectors is considerably less than the magnitude of its impact on the non-financial subsectors. In order to quantify this difference, the averages of absolute values of oil coefficients are calculated as 0.08 and 0.22 for the financials and non-financials, respectively.

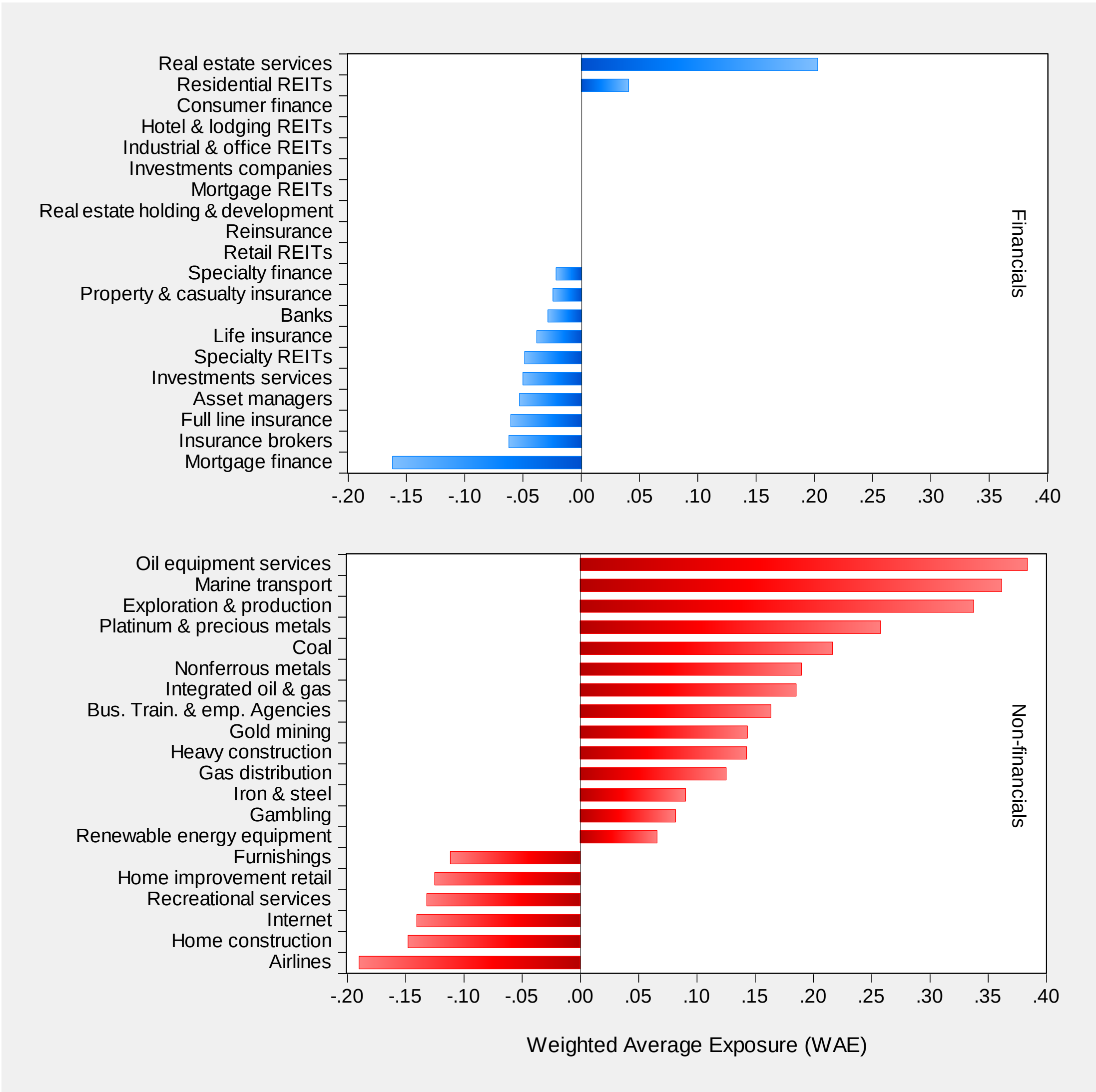


Figure 8. Oil price risk exposure of the subsectors (January 1983 to March 2015)

In order to be able to clarify and measure the magnitude and role of each risk factor in explaining the subsectors' returns, the WAE of all the other risk factors are calculated using the Eq. (18). Later, sum of the absolute values of the WAE of risk coefficients are calculated. Again for the sake of comparability of the financial and non-financial subsectors, the factor loadings of the Fama-French and oil risk factors are presented on percentage basis to imply the total impact magnitude of each risk sources. Figure 9 illustrates the proportion (percentage role) of each risk factor in explaining the subsectors' returns for the financial and non-financial (the 20 most sensitive) subsectors.

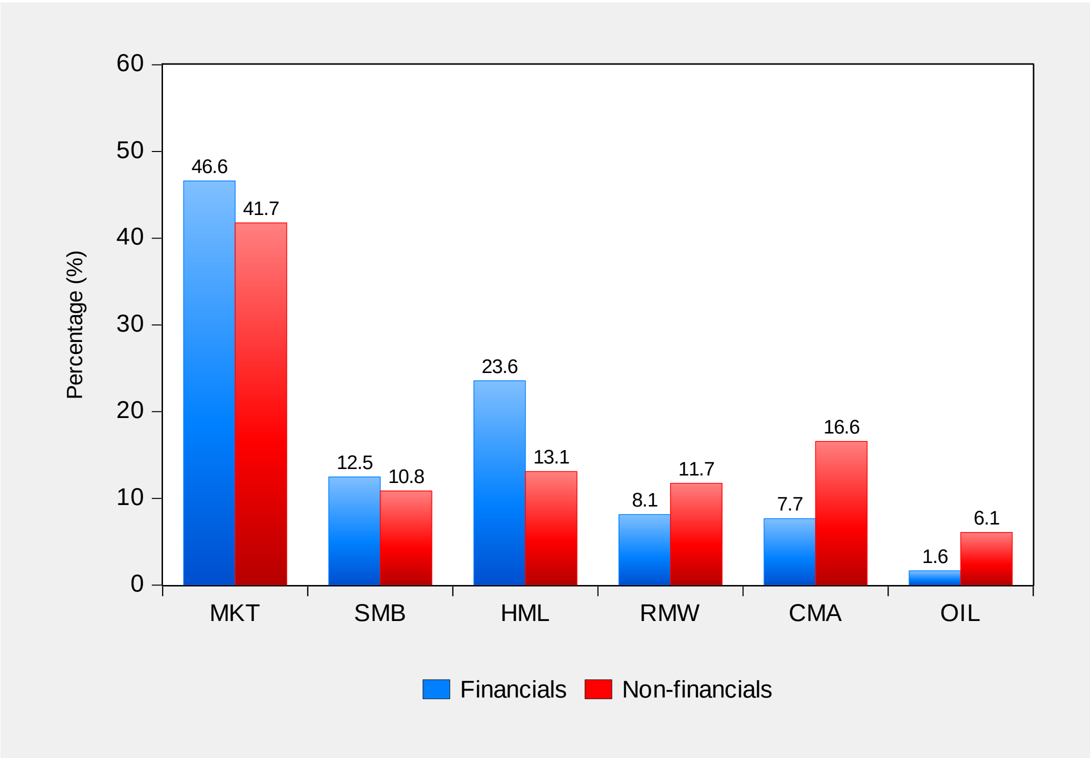


Figure 9. The proportion of risk factors in determining the subsectors' returns

As you can see from the figure, MKT, SMB and HML which are the risk factors in the FF3F model have relatively higher role in explaining the returns for the financial subsectors than those for the non-financial subsectors. Interestingly, the recently introduced Fama-French risk factors, RMW and CMA, along with OIL, play more important role in determining the equity returns for the non-financial subsectors than those for the financial subsectors. For the financial subsectors, MKT (46.6%), HML (23.6%), SMB (12.5%), RMW (8.1%), CMA (7.7%) and OIL (1.6%) risk factors have the highest proportion in explaining the stock returns, respectively. On the other hand, MKT (41.7%), CMA (16.6%), HML (13.1%), RMW (11.7%), SMB (10.8%), and OIL (6.1%) risk factors have the highest proportion in explaining the stock returns for the non-financial subsectors, respectively.

For the both types of subsectors, the monthly return on the market portfolio (MKT), which is calculated as the value-weighted return of all CRSP stocks incorporated in the U.S. in excess of the 1-month Treasury bill rate, has the highest share among other risk factors in determining the subsectors' returns. The second most important risk factor for the financials, HML, is the monthly return of a portfolio with high book-to-market ratio (a value portfolio) in excess of a portfolio with low book-to-market ratio (growth portfolio) which suggests the important role of book-to-market ratio in asset valuation of financial stocks. The second most important risk factor for the non-financials, CMA, is the monthly return of a portfolio with conservative investment strategies in excess of a portfolio with aggressive investment strategies. This indicates the importance of CMA in pricing non-financial stocks. However, the monthly return on West Texas Intermediate crude oil (OIL) has the least important role in explaining the subsectors' returns for the both financials and non-financials.

Table 9 reports the rankings of oil price risk exposures for the five most negatively and positively exposed subsectors in both the financial and non-financial subsectors using the WAE procedure. Among the financial subsectors, Mortgage Finance, Insurance Brokers, Full Line Insurance, Asset Managers, and Investment Services are those most negatively exposed to oil price risk. However, among the financial subsectors, only two, namely Real Estate Services and Residential REITs, are positively exposed to oil price risk. The list of positively exposed non-financials is dominated by the real estate-related subsectors, and this finding implies that, in general, real estate subsectors are positively related to oil prices.

Table 9. The oil price risk exposure of industry subsectors

Most negatively exposed subsectors (top five)	
Financials	Weighted Average Exposure (WAE)
Mortgage Finance	-0.162
Insurance Brokers	-0.062
Full Line Insurance	-0.060
Asset Managers	-0.053
Investment Services	-0.050
Non-Financials	
Airlines	-0.190
Home Construction	-0.147
Internet	-0.140
Recreational Services	-0.132
Home Improvement Retail	-0.125
Most positively exposed subsectors (top five)	
Financials	Weighted Average Exposure (WAE)
Real Estate Services	0.203
Residential REITs	0.041
-	-
-	-
-	-
Non-Financials	
Oil Equipment Services	0.384
Marine Transport	0.362
Exploration & Production	0.338
Platinum & Precious Metals	0.258
Coal	0.217

Note: The above subsectors are ranked based on their weighted-average of significant oil price coefficients in the breakpoint regression of the multifactor model.

Among the non-financial subsectors in Table 5, Airlines, Home Construction, Internet, Recreational Services, and Home Improvement Retail are ranked, respectively, as those most negatively exposed to oil price risk. Meanwhile, Oil Equipment Services, Marine Transport, Exploration & Production, Platinum & Precious Metals, and Coal are ranked, respectively, as the non-financial subsectors most positively exposed to the oil price risk. Oil Equipment Services is the most sensitive industry subsector to the oil price risk in the U.S. market, with a weighted-average oil price exposure of 0.384.

These results are consistent with most of the prior studies (Nandha and Faff, 2008; Kilian and Park, 2009; Arouri and Nguyen, 2010; Elyasiani et al., 2011) which find that the oil and gas industry in general is the most sensitive industry to oil price risk. However, these studies ignore the subsector sensitivities. Given the consistency with the existing literature for Airlines (e.g., Loudon, 2001; Mohanty et al., 2014), the substantial exposure of Airlines (-0.190) to oil price risk is still surprising in spite of the fact that most airline companies are expected to be hedged against oil price spikes. According to the oil exposure results, although these industry subsectors are affected by oil price changes, these impacts are, on average, limited compared with the impact of other explanatory factors in the FF5F model.

2.4.4 Time-varying Parameter Model

To check the robustness of the results in Table 7 and 8, a time-varying parameter model is employed to examine the stability of subsector equity returns and oil price relationships. As it is mentioned before, this model is in state-space form comprising the measurement and transition equations. Figure 10-13 exhibit the estimated time-varying oil price exposure of financial and non-financial subsectors along with its

90% confidence interval. The estimated coefficients are smoothed using the Kalman smoother as this enables us to obtain less noisy and more precise estimates relative to the Kalman filter. It should be noted that a point estimate of time-varying oil price exposure is considered significant only when the confidence interval around that point does not contain zero. The results of the time-varying exposure model are mostly consistent with the findings of the breakpoint regressions discussed before. As illustrated in Figure 10-13, the financial subsectors with highest time-varying exposure are Mortgage Finance, Full Line Insurance, Investment Services, and Real Estate Services. Accordingly, the subsector Oil Equipment Services has the highest time-varying oil price exposure, followed by Marine Transportation, Exploration & Production, Airlines, and Coal, respectively. The financial subsectors show a lower degree of time-varying exposure to oil price risk relative to non-financial subsectors.

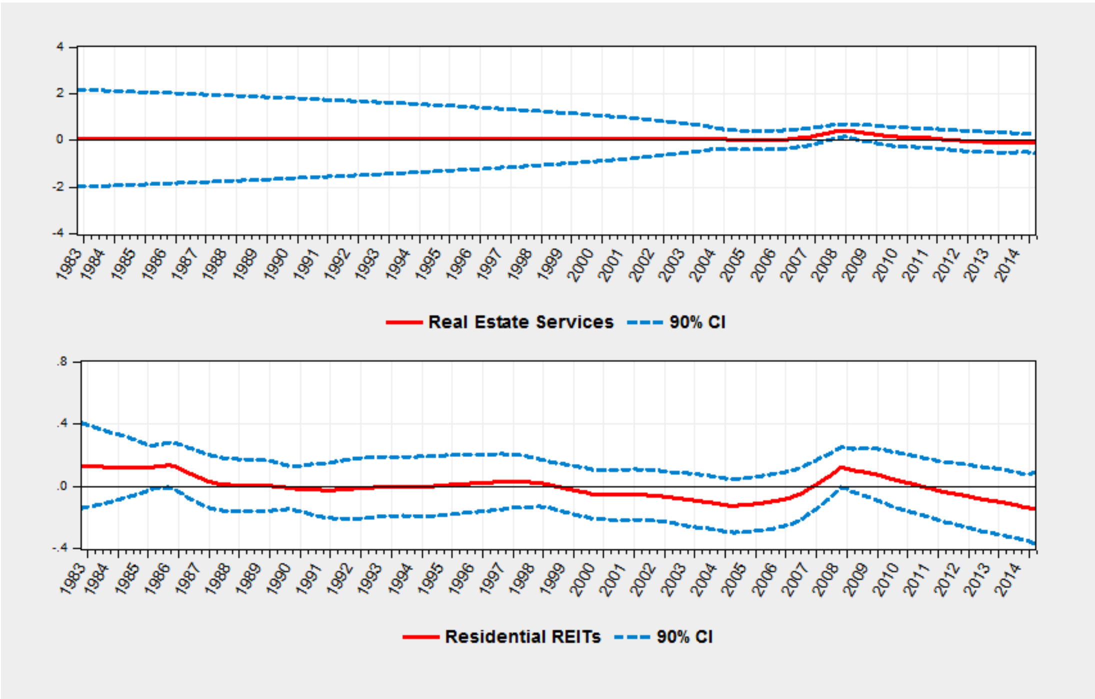


Figure 10. Time-varying oil price risk exposure (positively exposed financials)

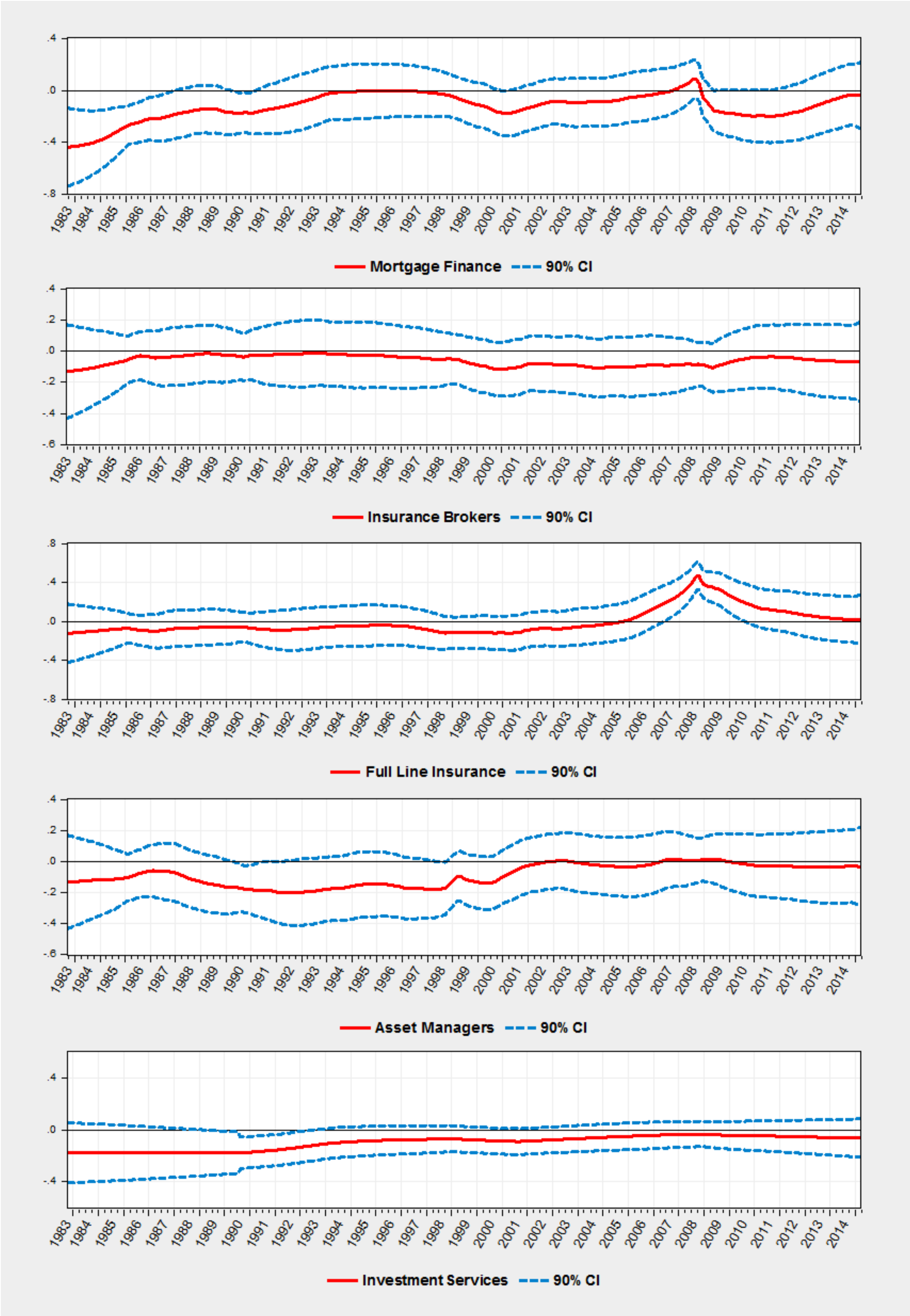


Figure 11. Time-varying oil price risk exposure (negatively exposed financials)

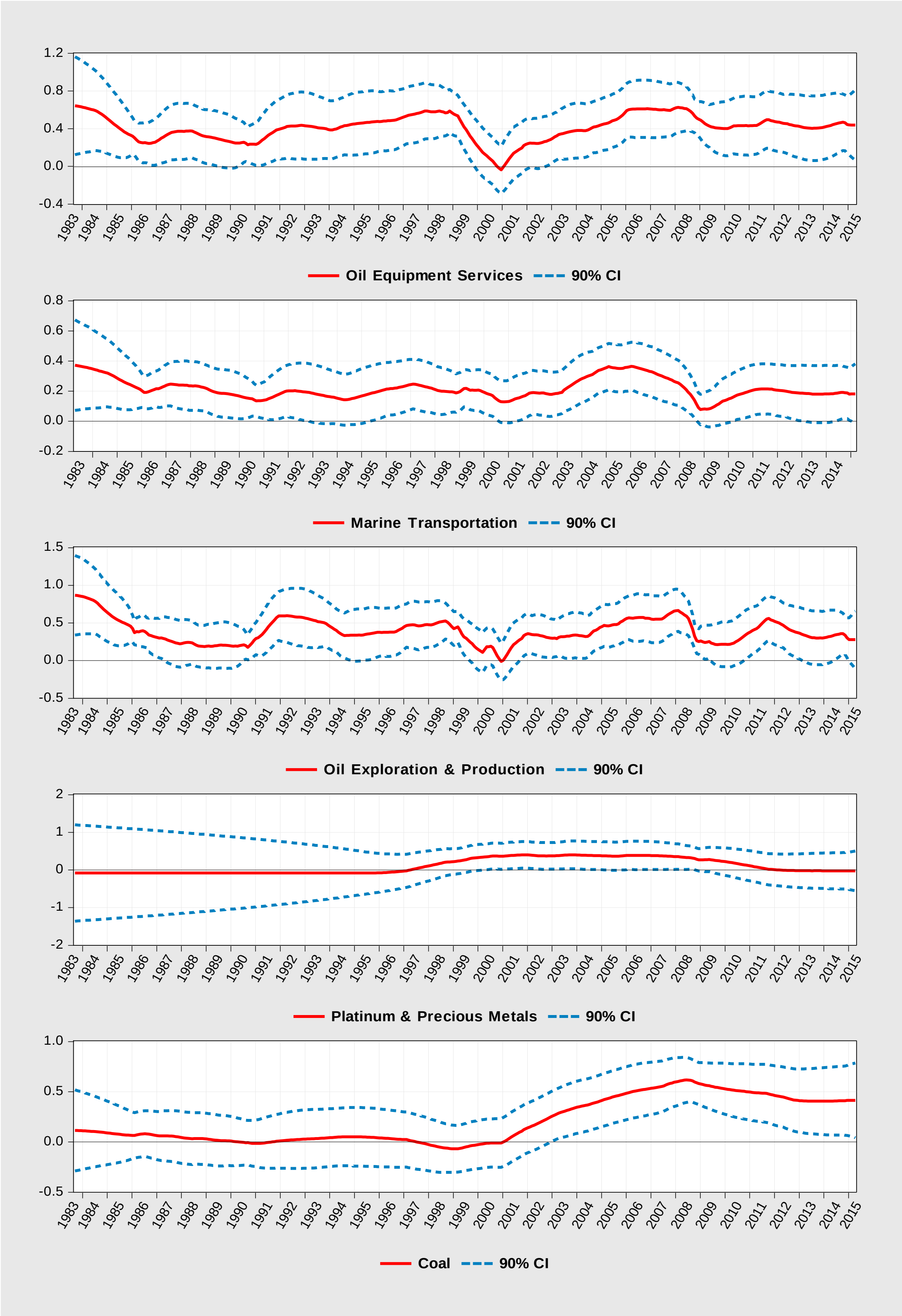


Figure 12. Time-varying oil price risk exposure (positively exposed non-financials)

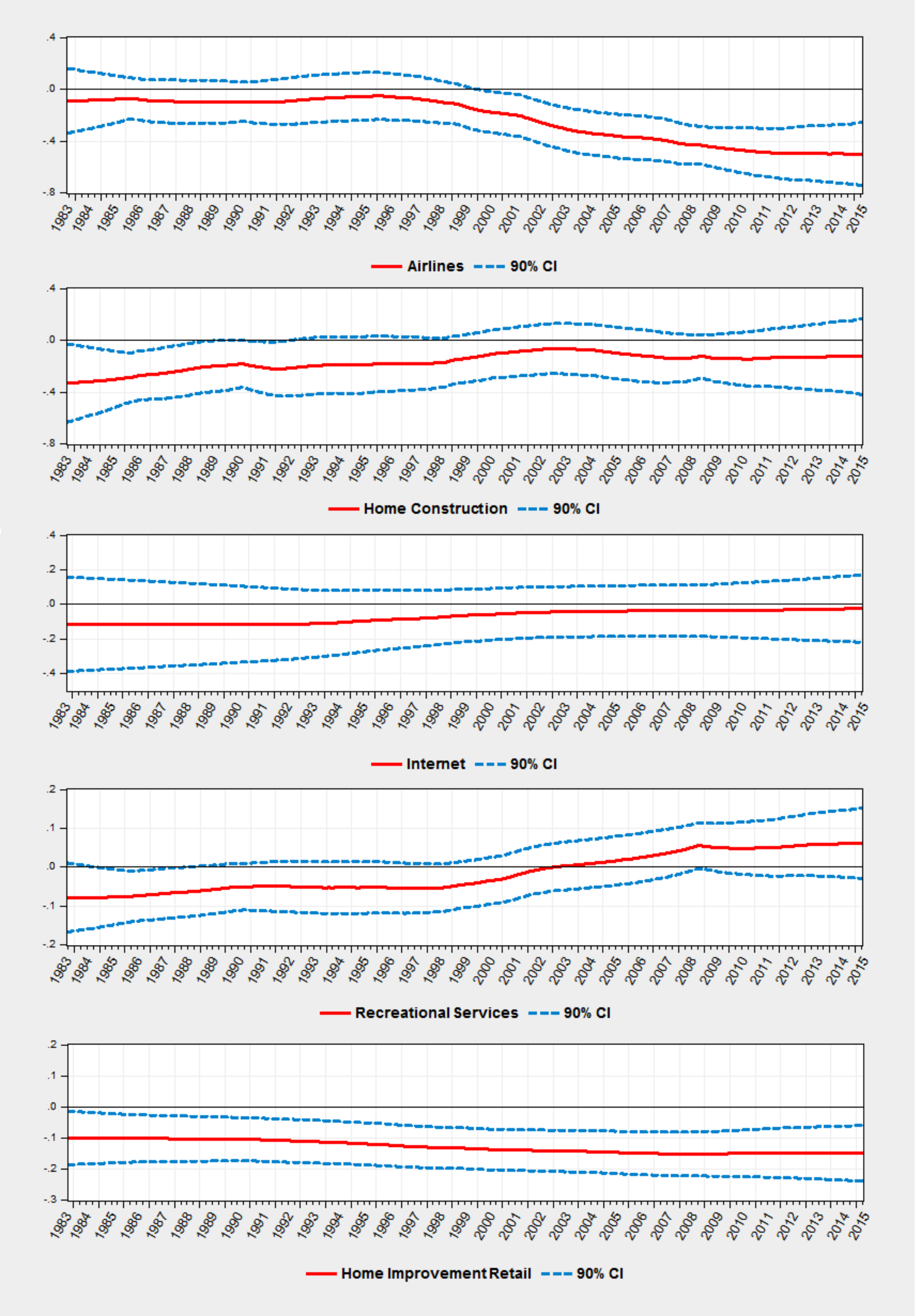


Figure 13. Time-varying oil price risk exposure (negatively exposed non-financials)

2.4.5 Time-varying Causality in Return

In order to test the return spillover between oil prices and the subsectors' returns, the causal linkages between them should be examined. This study employs the Hill's (2007) fixed-length rolling window causality test. He suggests a successive multi-horizon non-causality test, which can be adopted to detect non-linear causalities in terms of linear parametric restrictions for a trivariate process (two different time series plus an auxiliary variable). This study utilizes the bivariate case where causality between two different time series is measured. Therefore, the aim is to test the null hypothesis of non-causality running from oil prices (WTI) to the subsectors' returns. Causality takes place at any horizon if and only if it takes place at horizon 1 (first month in each window).

Due to likely substandard performance of the chi-squared distribution in small samples, Hill (2007) proposed a parametric bootstrapping approach for estimating small sample p-values. Also, the length rolling window is fixed at 60 months and the maximum order of the VAR model is 4 lags. Table 10 and 11 present the time-varying causality in return for the financial and non-financial subsectors, respectively.

For the financials, the rejection rate of null hypothesis implying time-varying non-causality in return ranges from 12.23% (Mortgage REITs) to 38.53% (Full Line Insurance). This means that, for instance, there is a causality running from oil to Full Line Insurance 38.53% of the time. For the non-financials, the rejection rate of null hypothesis implying time-varying non-causality in return ranges from 2.14% (Mobile Telecommunications) to 53.52% (Auto Parts).

Table 10. Time-varying causality in return for financial subsectors

Null hypothesis (H_0)			Avg. VAR order	Avg. BPV	Rejection rate of H_0
Oil	$\nrightarrow$	Asset Managers	1.6177	0.2505	24.1590
Oil	$\nrightarrow$	Banks	1.7554	0.2767	34.2508
Oil	$\nrightarrow$	Consumer Finance	1.5902	0.2578	28.7462
Oil	$\nrightarrow$	Full Line Insurance	1.5046	0.3435	38.5321
Oil	$\nrightarrow$	Hotel & Lodging REITs	1.9450	0.2078	33.9450
Oil	$\nrightarrow$	Industrial & Office REITs	1.9692	0.3031	27.8287
Oil	$\nrightarrow$	Insurance Brokers	1.6728	0.2737	32.7217
Oil	$\nrightarrow$	Investment Companies	4.0000	0.6440	29.9694
Oil	$\nrightarrow$	Investment Services	1.6422	0.2155	14.3731
Oil	$\nrightarrow$	Life Insurance	1.8471	0.3834	34.8624
Oil	$\nrightarrow$	Mortgage Finance	1.6453	0.2671	20.1835
Oil	$\nrightarrow$	Mortgage REITs	4.0000	0.5436	12.2324
Oil	$\nrightarrow$	Property & Casualty Insurance	1.8287	0.3525	26.9113
Oil	$\nrightarrow$	Real Estate Holding & Development	1.8685	0.3698	21.7125
Oil	$\nrightarrow$	Real Estate Services	4.0000	0.5014	14.5455
Oil	$\nrightarrow$	Reinsurance	1.3945	0.2424	29.3578
Oil	$\nrightarrow$	Residential REITs	1.8165	0.2209	33.6391
Oil	$\nrightarrow$	Retail REITs	1.7401	0.4154	29.0520
Oil	$\nrightarrow$	Specialty Finance	1.6177	0.2804	26.6055
Oil	$\nrightarrow$	Specialty REITs	1.9664	0.2011	32.1101

Notes: $\nrightarrow$ denotes the non-causality null hypothesis. VAR denotes Vector Autoregressive model and BPV denotes the bootstrap P-values. The maximum order of VAR model is 4 lags. Size of the fixed rolling-window is 60 months. Bootstrap iterations are 1000 times. BPV of less than 5% indicates causality within that window.

Figure 14 and 15 exhibit the subsectors which receive the highest level of return spillover from crude oil. Among the financials, Full Line Insurance, Life Insurance, Banks, Hotel & Lodging REITs, and Residential REITs are the top subsectors receiving highest causality in return from oil market. For the non-financials, Auto Parts, Electronic Office Equipment, Tires, Furnishings, and Commodity Chemicals are the top subsectors which receive the highest level of return spillover from crude oil during the period of the study. In these figures, the U.S. recessions are highlighted in gray. Interestingly, after the 1990-91 and 2008-09 recessions, there are high levels of causality in return running from oil market to financial and non-financial subsectors. This may be due to the higher demand and more dependency on oil during the expansionary phase of the economic cycle. Nonetheless, this is not often the case for the 2001 recession perhaps because it was very short-lived and shallow.

Table 11. Time-varying causality in return for non-financial subsectors

Null hypothesis (H_0)			Avg. VAR order	Avg. BPV	Rejection rate of H_0
Oil	$\nrightarrow$	Aerospace	1.6942	0.2863	29.9694
Oil	$\nrightarrow$	Airlines	1.4862	0.4412	12.2324
Oil	$\nrightarrow$	Alternative Electricity	1.8318	0.2986	23.5474
Oil	$\nrightarrow$	Aluminum	1.5413	0.3096	42.8135
Oil	$\nrightarrow$	Apparel Retailers	1.7187	0.3582	29.9694
Oil	$\nrightarrow$	Auto Parts	1.7951	0.2270	53.5168
Oil	$\nrightarrow$	Automobiles	1.6453	0.2615	32.1101
Oil	$\nrightarrow$	Biotechnology	1.4771	0.4061	19.8777
Oil	$\nrightarrow$	Brewers	1.4679	0.4132	16.8196
Oil	$\nrightarrow$	Broadcasting & Entertainment	1.6758	0.3946	14.6789
Oil	$\nrightarrow$	Broadline Retailers	1.5780	0.4277	20.7951
Oil	$\nrightarrow$	Building Materials & Fixtures	1.7615	0.2780	36.3914
Oil	$\nrightarrow$	Business Support Services	1.6024	0.3166	31.1927
Oil	$\nrightarrow$	Business Training & Employment Agencies	1.8805	0.4311	39.4495
Oil	$\nrightarrow$	Clothing & Accessories	1.7003	0.3109	28.7462
Oil	$\nrightarrow$	Coal	1.5902	0.4790	18.0428
Oil	$\nrightarrow$	Commercial Vehicles & Trucks	1.5138	0.2867	31.8043
Oil	$\nrightarrow$	Commodity Chemicals	1.5138	0.2031	44.0367
Oil	$\nrightarrow$	Computer Hardware	1.3547	0.3584	15.9021
Oil	$\nrightarrow$	Computer Services	1.5627	0.3651	20.1835
Oil	$\nrightarrow$	Consumer Electronics	1.5125	0.3408	16.2080
Oil	$\nrightarrow$	Containers & Packaging	1.4862	0.3007	33.0275
Oil	$\nrightarrow$	Conventional Electricity	1.8379	0.3746	22.6300
Oil	$\nrightarrow$	Defense	1.5657	0.3738	19.8777
Oil	$\nrightarrow$	Delivery Services	1.8012	0.3787	19.8777
Oil	$\nrightarrow$	Distillers & Vintners	2.0948	0.4069	13.7615
Oil	$\nrightarrow$	Diversified Industrials	1.7584	0.2871	26.9113
Oil	$\nrightarrow$	Drug Retailers	1.7064	0.2169	34.5566
Oil	$\nrightarrow$	Durable Household Products	1.6667	0.2356	39.7554
Oil	$\nrightarrow$	Electrical Components & Equipment	1.8135	0.2773	31.4985
Oil	$\nrightarrow$	Electronic Equipment	1.4862	0.3730	20.1835
Oil	$\nrightarrow$	Electronic Office Equipment	1.8410	0.1943	52.2936
Oil	$\nrightarrow$	Exploration & Production	1.7982	0.4652	12.2324
Oil	$\nrightarrow$	Farming & Fishing	4.0000	0.5084	29.6636
Oil	$\nrightarrow$	Financial Administration	1.7554	0.2623	31.4985
Oil	$\nrightarrow$	Fixed Line Telecommunications	1.6514	0.4059	13.7615
Oil	$\nrightarrow$	Food Products	1.8777	0.3354	23.5474
Oil	$\nrightarrow$	Food Retailers & Wholesalers	1.6330	0.3213	26.2997
Oil	$\nrightarrow$	Footwear	1.5994	0.3259	30.5810
Oil	$\nrightarrow$	Forestry	4.0000	0.4929	11.9403
Oil	$\nrightarrow$	Furnishings	1.7737	0.1971	47.0948
Oil	$\nrightarrow$	Gambling	1.7554	0.3574	26.6055
Oil	$\nrightarrow$	Gas Distribution	1.3578	0.3893	7.0336
Oil	$\nrightarrow$	Gold Mining	1.6055	0.3630	12.5382

Note: See Table 10.

Table 11: Continued

Null hypothesis (H_0)		Avg. VAR order	Avg. BPV	Rejection rate of H_0
Oil $\nrightarrow$	Health Care Providers	1.5015	0.3631	18.6544
Oil $\nrightarrow$	Heavy Construction	1.5260	0.3987	19.5719
Oil $\nrightarrow$	Home Construction	1.5413	0.4205	25.3823
Oil $\nrightarrow$	Home Improvement Retailers	1.5963	0.3518	20.1835
Oil $\nrightarrow$	Hotels	1.7645	0.3401	40.0612
Oil $\nrightarrow$	Industrial Machinery	1.7095	0.2115	43.4251
Oil $\nrightarrow$	Industrial Suppliers	1.6483	0.3938	25.6881
Oil $\nrightarrow$	Integrated Oil & Gas	1.3639	0.4493	13.1498
Oil $\nrightarrow$	Internet	4.0000	0.5099	10.7034
Oil $\nrightarrow$	Iron & Steel	1.4220	0.3367	21.4067
Oil $\nrightarrow$	Marine Transportation	1.4648	0.4653	22.9358
Oil $\nrightarrow$	Media Agencies	1.7676	0.3092	27.5229
Oil $\nrightarrow$	Medical Equipment	1.5810	0.2786	25.3823
Oil $\nrightarrow$	Medical Supplies	1.5076	0.4233	13.4557
Oil $\nrightarrow$	Mobile Telecommunications	1.8930	0.5835	2.1407
Oil $\nrightarrow$	Multiutilities	1.6453	0.4123	21.7125
Oil $\nrightarrow$	Nondurable Household Products	1.8226	0.3674	31.1927
Oil $\nrightarrow$	Nonferrous Metals	1.4190	0.3548	30.5810
Oil $\nrightarrow$	Oil Equipment & Services	1.4434	0.4859	5.1988
Oil $\nrightarrow$	Paper	1.6636	0.2690	39.4495
Oil $\nrightarrow$	Personal Products	1.8410	0.3152	27.8287
Oil $\nrightarrow$	Pharmaceuticals	1.4373	0.3744	17.7370
Oil $\nrightarrow$	Pipelines	1.4373	0.4256	6.7278
Oil $\nrightarrow$	Platinum & Precious Metals	4.0000	0.4610	8.8889
Oil $\nrightarrow$	Publishing	1.8196	0.2516	34.8624
Oil $\nrightarrow$	Railroads	1.4801	0.3426	33.3333
Oil $\nrightarrow$	Recreational Products	2.1223	0.3264	34.2508
Oil $\nrightarrow$	Recreational Services	1.4343	0.3673	27.5229
Oil $\nrightarrow$	Renewable Energy Equipment	4.0000	0.4168	20.1835
Oil $\nrightarrow$	Restaurants & Bars	1.6544	0.3275	18.6544
Oil $\nrightarrow$	Semiconductors	1.6300	0.3343	18.6544
Oil $\nrightarrow$	Soft Drinks	1.5719	0.3954	20.1835
Oil $\nrightarrow$	Software	1.6820	0.2966	22.6300
Oil $\nrightarrow$	Specialty Chemicals	1.4343	0.3357	18.3486
Oil $\nrightarrow$	Specialized Consumer Services	1.7370	0.4514	11.9266
Oil $\nrightarrow$	Specialty Retailers	1.9113	0.2617	32.7217
Oil $\nrightarrow$	Telecommunications Equipment	1.8287	0.3674	22.6300
Oil $\nrightarrow$	Tires	1.8440	0.2149	51.3761
Oil $\nrightarrow$	Tobacco	1.6208	0.2814	32.4159
Oil $\nrightarrow$	Toys	1.4281	0.2914	26.6055
Oil $\nrightarrow$	Transportation Services	1.9144	0.3720	22.6300
Oil $\nrightarrow$	Travel & Tourism	1.5505	0.4405	20.7951
Oil $\nrightarrow$	Trucking	1.4220	0.3503	31.4985
Oil $\nrightarrow$	Waste & Disposal Services	1.7554	0.4121	18.9602
Oil $\nrightarrow$	Water	1.6361	0.4165	21.1009

Note: See Table 10.

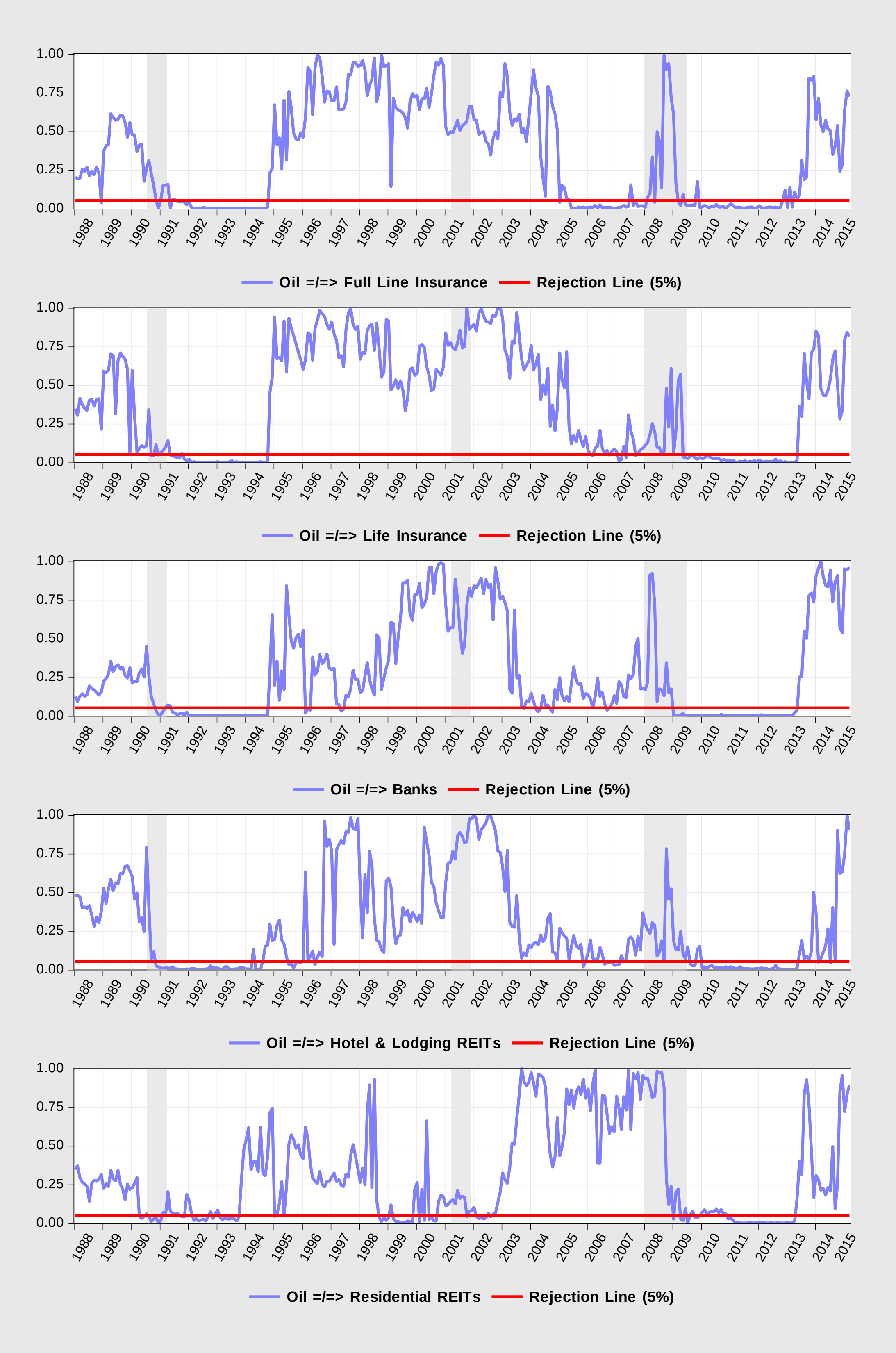


Figure 14. Time-varying causality in return (top-five financial subsectors)

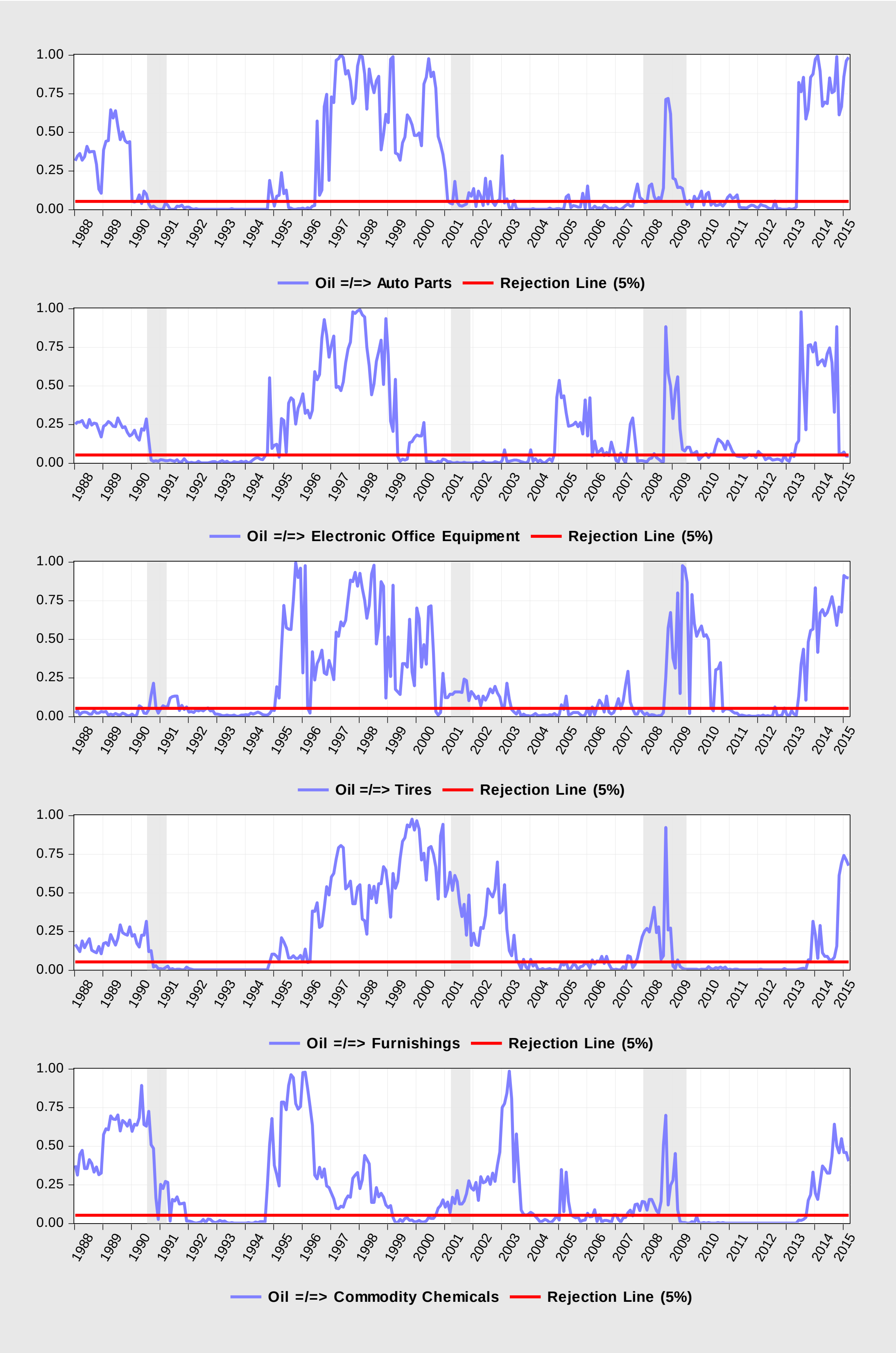


Figure 15. Time-varying causality in return (top-five non-financial subsectors)

2.4.6 Time-varying Causality in Risk

For the aim of testing the risk spillover between oil prices and the subsectors' returns, the causal relationships between them should be examined. In this case, the same methodology of Hill's (2007) time-varying causality will be applied here. As it is pointed out before, the only difference is that instead of the oil and subsectors' returns, their value-at-risks (VaRs) will be used to measure the risk spillover from crude oil market to the subsectors. The main motivation to explore the risk spillover between these markets is "financial contagion" in the event of worldwide crisis, which makes them to be exposed to a same shock.

2.4.6.1 Estimation of EGARCH Model

The VaR methodology is used to measure market risk, since it shows market risk through the probability distribution of a random variable and appraises the risk with a single real number. This study uses variance-covariance method based on the generalized autoregressive conditional heteroscedasticity (GARCH) family model for VaR estimation. But before using the GARCH family models, the existence of ARCH effect in the return series should be confirmed specially for the WTI series which is prone to have substantial volatility clustering. Consequently, the ARCH-LM test (Engle, 1982) is applied on the residual of all the series. Table 11-13 exhibit the results of the ARCH-LM test and Ljung–Box test statistics for autocorrelation for the financial and non-financial subsectors along with the WTI. The results confirm the existence of a high-order ARCH effect or volatility clustering as the null hypothesis of homoscedasticity is rejected for almost all the series. Also, the null hypothesis of no autocorrelation is also rejected for most of the squared residuals of the return series. Thus, it is essential to employ a GARCH family model here.

As it is explained before, the stock and commodity prices react asymmetrically to shocks (Cont, 2001). A negative past return affects the current volatility more considerably than a positive return. Accordingly, when using financial data, it is necessary to use a GARCH model which identifies the asymmetry effect. There are two renowned asymmetric GARCH models namely the Threshold GARCH or TGARCH which introduced by Zakoian (1994) and the exponential GARCH or EGARCH which proposed by Nelson (1991).

Table 12. Diagnostics tests before EGARCH estimation for the WTI

Series	ARCH-LM	P-value	$Q^2(20)$	P-value
WTI crude oil	30.4284	0.000	75.499	0.000

Note: ARCH-LM is Engle's (1982) Lagrange multiplier test for the heteroscedasticity in the residual of the return series up to order 20. $Q^2(20)$ is the Ljung–Box test statistics for serial correlation in the squared standardized residuals with 20 lags.

Table 13. Diagnostics tests before EGARCH estimation for the financials

Subsector	ARCH-LM	P-value	$Q^2(20)$	P-value
Asset Managers	8.110	0.005	51.870	0.000
Banks	39.811	0.000	225.760	0.000
Consumer Finance	29.361	0.000	34.421	0.023
Full Line Insurance	89.564	0.000	156.190	0.000
Hotel & Lodging REITs	26.447	0.000	47.318	0.001
Industrial & Office REITs	20.300	0.000	76.495	0.000
Insurance Brokers	6.518	0.011	25.152	0.196
Investment Companies	15.851	0.000	42.934	0.002
Investment Services	17.120	0.000	26.266	0.157
Life Insurance	5.817	0.016	130.190	0.000
Mortgage Finance	235.487	0.000	301.240	0.000
Mortgage REITs	15.779	0.000	23.240	0.277
Property & Casualty Insurance	12.462	0.001	117.180	0.000
Real Estate Holding & Development	11.609	0.001	47.422	0.001
Real Estate Services	2.890	0.092	36.342	0.014
Reinsurance	18.118	0.000	33.431	0.030
Residential REITs	17.482	0.000	51.866	0.000
Retail REITs	15.211	0.000	117.910	0.000
Specialty Finance	22.876	0.000	126.470	0.000
Specialty REITs	6.122	0.014	62.001	0.000

Note: See Table 12.

Table 14. Diagnostics tests before EGARCH estimation for the non-financials

Subsectors	ARCH-LM	P-value	$Q^2(20)$	P-value
Aerospace	2.942	0.087	36.183	0.017
Airlines	3.919	0.049	35.722	0.017
Alternative Electricity	13.576	0.000	144.260	0.000
Aluminum	16.035	0.000	44.217	0.001
Apparel Retailers	20.528	0.000	39.736	0.005
Auto Parts	27.076	0.000	63.696	0.000
Automobiles	4.404	0.037	129.480	0.000
Biotechnology	9.370	0.002	83.134	0.000
Brewers	5.230	0.021	45.019	0.001
Broadcasting & Entertainment	3.170	0.076	64.227	0.000
Broadline Retailers	16.454	0.000	43.316	0.002
Building Materials & Fixtures	31.052	0.000	36.849	0.012
Business Support Services	34.103	0.000	25.041	0.201
Business Training & Employment Agencies	6.132	0.016	36.845	0.012
Clothing & Accessories	10.314	0.001	28.548	0.097
Coal	26.912	0.000	55.868	0.000
Commercial Vehicles & Trucks	11.578	0.001	31.490	0.049
Commodity Chemicals	14.881	0.000	56.590	0.000
Computer Hardware	29.361	0.000	144.710	0.000
Computer Services	15.938	0.000	22.916	0.293
Consumer Electronics	14.735	0.000	31.423	0.076
Containers & Packaging	3.558	0.060	31.385	0.050
Conventional Electricity	23.856	0.000	43.376	0.002
Defense	6.502	0.011	35.386	0.018
Delivery Services	18.125	0.000	82.169	0.000
Distillers & Vintners	2.625	0.106	29.610	0.076
Diversified Industrials	8.152	0.005	80.888	0.000
Drug Retailers	3.857	0.050	34.673	0.022
Durable Household Products	9.538	0.002	70.581	0.000
Electrical Components & Equipment	10.161	0.002	39.200	0.006
Electronic Equipment	34.134	0.000	475.330	0.000
Electronic Office Equipment	3.199	0.075	36.315	0.016
Exploration & Production	8.328	0.004	31.117	0.054
Farming & Fishing	26.062	0.000	45.117	0.001
Financial Administration	5.830	0.018	35.734	0.017
Fixed Line Telecommunications	11.431	0.001	174.200	0.000
Food Products	7.015	0.008	64.198	0.000
Food Retailers & Wholesalers	3.719	0.052	25.903	0.169
Footwear	8.516	0.004	74.024	0.000
Forestry	10.903	0.001	99.198	0.000
Furnishings	54.925	0.000	171.940	0.000
Gambling	1.835	0.176	93.324	0.000
Gas Distribution	36.150	0.000	176.600	0.000
Gold Mining	6.405	0.042	45.682	0.010

Note: See Table 12.

Table 14. Continued

Subsectors	ARCH-LM	P-value	$Q^2(20)$	P-value
Health Care Providers	10.114	0.001	20.098	0.452
Heavy Construction	23.610	0.000	44.437	0.001
Home Construction	8.952	0.003	35.040	0.021
Home Improvement Retailers	1.764	0.185	30.101	0.058
Hotels	4.087	0.044	50.915	0.000
Industrial Machinery	8.252	0.005	32.369	0.040
Industrial Suppliers	3.758	0.056	31.577	0.049
Integrated Oil & Gas	3.928	0.048	32.194	0.041
Internet	26.726	0.000	157.420	0.000
Iron & Steel	23.381	0.000	43.131	0.002
Marine Transportation	6.317	0.012	43.708	0.002
Media Agencies	12.137	0.000	28.020	0.109
Medical Equipment	31.123	0.000	52.391	0.000
Medical Supplies	6.374	0.012	47.379	0.001
Mobile Telecommunications	28.622	0.000	133.580	0.000
Multiutilities	6.115	0.014	22.642	0.307
Nondurable Household Products	3.776	0.053	30.344	0.064
Nonferrous Metals	31.628	0.000	48.642	0.000
Oil Equipment & Services	19.085	0.000	34.188	0.025
Paper	39.274	0.000	214.100	0.000
Personal Products	3.085	0.080	57.171	0.000
Pharmaceuticals	3.188	0.075	52.941	0.000
Pipelines	8.021	0.005	226.620	0.000
Platinum & Precious Metals	4.244	0.041	71.619	0.000
Publishing	9.121	0.003	30.232	0.066
Railroads	89.564	0.000	30.956	0.066
Recreational Products	6.014	0.018	66.225	0.000
Recreational Services	12.837	0.000	80.996	0.000
Renewable Energy Equipment	9.274	0.009	31.018	0.053
Restaurants & Bars	5.609	0.018	34.951	0.020
Semiconductors	4.496	0.035	120.820	0.000
Soft Drinks	12.954	0.000	79.328	0.000
Software	16.664	0.000	228.340	0.000
Specialty Chemicals	16.104	0.000	29.047	0.087
Specialized Consumer Services	6.013	0.015	195.740	0.000
Specialty Retailers	4.150	0.042	33.879	0.027
Telecommunications Equipment	20.749	0.000	102.040	0.000
Tires	14.381	0.000	110.710	0.000
Tobacco	9.694	0.002	46.083	0.001
Toys	10.569	0.001	20.566	0.423
Transportation Services	18.825	0.000	37.270	0.011
Travel & Tourism	39.611	0.000	53.237	0.000
Trucking	4.640	0.039	32.367	0.061
Waste & Disposal Services	5.335	0.021	47.681	0.000
Water	4.534	0.034	39.275	0.006

Note: See Table 12.

Therefore, both of the EGARCH and TGARCH models have been tested on the data in order to find out which one is more suitable for this study. Given the requirements of having significant model coefficients and the minimum AIC, the EGARCH(1,1) model is chosen as the best model after numerous trials. So, this model is used to explore the volatility features of the subsectors and WTI returns. Due to the fat-tailed structure of the return series, the generalized error distribution (GED) is applied to describe the residual of the selected GARCH model. Table 14-16 exhibit the estimation results of EGARCH for the WTI, financial and non-financial subsectors.

Table 15. Estimation results of EGARCH model for the WTI

Series	Φ	ω	α	β	γ	GED	AIC	Log Likelihood
WTI crude oil	0.001	-0.992*	0.514*	0.880*	-0.055	1.681*	-2.088	410.070

Note: *, **, *** denote 1%, 5%, and 10% level of statistical significance, respectively. GED denotes the generalized error distribution degree parameter. AIC refers to the Akaike Information Criterion.

Table 16. Estimation results of EGARCH model for the financials

Subsectors	Φ	ω	α	β	γ	GED	AIC	Log Likelihood
Asset Managers	0.012*	-0.348**	0.227*	0.966*	-0.056	1.563*	-2.065	405.731
Banks	0.008*	-0.714**	0.254*	0.91*	-0.123**	1.481*	-2.894	565.995
Consumer Finance	0.012*	-0.573***	0.175***	0.919*	-0.077***	1.384*	-2.56	501.531
Full Line Insurance	0.009*	-0.607*	0.304*	0.932*	-0.131*	1.321*	-2.667	522.145
Hotel & Lodging REITs	0.009*	-0.46**	0.219*	0.939*	-0.075**	1.131*	-2.151	422.274
Industrial & Office REITs	0.006**	-0.451***	0.131	0.937*	-0.143*	1.257*	-2.751	446.245
Insurance Brokers	0.009*	-1.007***	0.277**	0.86*	-0.040	1.320*	-2.877	562.823
Investment Companies	0.011*	-0.201	-0.003	0.967*	-0.241*	1.006*	-2.203	239.591
Investment Services	0.011*	-0.473**	0.215*	0.937*	-0.086**	1.515*	-1.969	387.023
Life Insurance	0.013*	-0.781*	0.223**	0.893*	-0.217*	1.256*	-2.785	544.991
Mortgage Finance	0.011*	-0.565*	0.287*	0.932*	-0.085**	1.366*	-2.176	427.087
Mortgage REITs	0.000	-9.815*	0.293	-0.749*	-0.010	1.354*	-2.632	282.362
Property & Casualty Insurance	0.009*	-0.652*	0.236*	0.922*	-0.108*	1.664*	-3.148	615.163
Real Estate Holding & Dev.	0.013*	-0.982***	0.174***	0.827*	-0.088	1.183*	-2.117	415.821
Real Estate Services	0.016**	-0.601***	0.367**	0.927*	-0.158***	1.235*	-1.523	105.019
Reinsurance	0.005***	-0.746***	0.167	0.892*	-0.149**	1.218*	-3.018	455.75
Residential REITs	0.006*	-0.305	0.125***	0.962*	-0.037	1.082*	-2.938	574.526
Retail REITs	0.009*	-0.570**	0.228*	0.931*	-0.071	1.212*	-3.069	600.04
Specialty Finance	0.011*	-1.020*	0.252*	0.859*	-0.171**	1.553*	-2.977	582.24
Specialty REITs	0.009*	-0.511***	0.209**	0.939*	-0.028	1.415*	-2.886	563.315

Note: See Table 15.

Table 17. Estimation results of EGARCH model for the non-financials

Subsectors	Φ	ω	α	β	γ	GED	AIC	Log Likelihood
Aerospace	0.011*	-0.707**	0.197***	0.903*	-0.111	1.342*	-2.903	567.769
Airlines	0.007***	-3.172*	0.318**	0.408**	-0.243*	1.706*	-2.066	405.845
Alternative Electricity	0	-0.844**	0.209**	0.883*	-0.152**	1.804*	-2.966	522.089
Aluminum	0.007***	-0.692*	0.252*	0.895*	-0.071	1.380*	-1.943	382.132
Apparel Retailers	0.011*	-0.952*	0.37*	0.867*	-0.147*	1.778*	-2.083	409.111
Auto Parts	0.008*	-0.936**	0.186***	0.862*	-0.194*	1.373*	-2.879	563.273
Automobiles	0.002	-0.45**	0.22*	0.944*	-0.096**	1.625*	-2.118	415.847
Biotechnology	0.016*	-0.171**	0.122**	0.985*	0.067*	1.458*	-2.075	405.566
Brewers	0.01*	-0.339**	0.081***	0.953*	0.093*	1.933*	-2.986	583.875
Broadcasting & Entertainment	0.011*	-0.463**	0.286*	0.955*	-0.081**	1.793*	-2.37	464.662
Broadline Retailers	0.007*	-2.275*	0.455*	0.662*	-0.133**	1.708*	-2.814	550.608
Building Materials & Fixtures	0.011*	-0.892***	0.212**	0.866*	-0.113***	1.246*	-2.634	515.808
Business Support Services	0.011*	-0.534***	0.144***	0.928*	-0.058	1.310*	-3.003	587.138
Business Train. & Emp. Agencies	0.015*	-0.652	0.256**	0.907*	-0.094***	1.714*	-1.976	288.697
Clothing & Accessories	0.012*	-1.094*	0.325*	0.839*	-0.189*	1.330*	-2.422	474.657
Coal	0.006	-0.295***	0.163**	0.961*	0.024	1.446*	-1.679	330.974
Commercial Vehicles & Trucks	0.01*	-1.305**	0.266*	0.788*	-0.121**	1.460*	-2.345	459.911
Commodity Chemicals	0.008*	-1.214**	0.146	0.804*	-0.194**	1.409*	-2.777	543.525
Computer Hardware	0.009*	-0.523***	0.204*	0.931*	-0.026**	1.815*	-2.419	474.241
Computer Services	0.009*	-1.176	0.15	0.815*	-0.132***	1.329*	-2.908	568.827
Consumer Electronics	0.018*	-0.376	0.118	0.929*	-0.049	1.398*	-1.183	207.705
Containers & Packaging	0.009*	-2.041*	0.051	0.65*	-0.328*	1.372*	-2.848	557.277
Conventional Electricity	0.005*	-7.103	0.014	-0.122	0.097	1.462*	-3.475	678.543
Defense	0.015*	-0.497*	0.225**	0.945*	-0.074	1.191*	-3.043	594.981
Delivery Services	0.005***	-0.512**	0.243*	0.937*	-0.061	1.457*	-2.355	461.796
Distillers & Vintners	0.009*	-1.31**	0.253**	0.801*	-0.23*	1.503*	-2.749	538.075
Diversified Industrials	0.007*	-0.452**	0.23*	0.953*	-0.046	1.384*	-3.06	598.256
Drug Retailers	0.011*	-1.088*	0.047	0.814*	-0.232*	1.489*	-2.733	534.929
Durable Household Products	0.007**	-2.059*	0.388*	0.68*	-0.386*	1.468*	-2.647	518.35
Electrical Comp. & Equipment	0.01*	-1.549*	0.282*	0.763*	-0.207*	1.522*	-2.759	540.059
Electronic Equipment	0.009*	-0.452*	0.264*	0.953*	-0.032	1.402*	-2.456	481.3
Electronic Office Equipment	0.005	-0.62*	0.267*	0.921*	-0.133*	1.365*	-2.43	476.327
Exploration & Production	0.006***	-2.268*	0.222***	0.611*	-0.262*	1.642*	-2.53	495.608
Farming & Fishing	0.012**	-2.294**	0.567*	0.633*	-0.277*	1.999*	-2.134	191.678
Financial Administration	0.012*	-0.904**	0.297*	0.885*	-0.1***	1.427*	-3.051	596.445
Fixed Line Telecommunications	0.006**	-0.464***	0.208*	0.949*	-0.009	1.631*	-3.129	611.603
Food Products	0.009*	-0.573**	0.262*	0.941*	-0.006	1.477*	-3.51	685.341
Food Retailers & Wholesalers	0.011*	-6.187*	-0.076	-0.063	-0.241**	1.350*	-3.041	594.565
Footwear	0.014*	-0.201**	0.161*	0.984*	-0.009	1.349*	-1.998	392.779
Forestry	-0.001	-0.201	-0.219	0.924*	-0.253*	1.206*	-2.864	130.607
Furnishings	0.009*	-0.865**	0.194***	0.864*	-0.159**	1.610*	-2.378	466.257
Gambling	0.011**	-0.386***	0.06	0.926*	-0.129*	1.239*	-1.758	346.275
Gas Distribution	0.009*	-1.66*	0.314*	0.762*	-0.203*	1.428*	-3.12	609.827
Gold Mining	0.002	-0.773	0.197**	0.862*	0.067	1.499*	-1.678	330.759

Note: See Table 15.

Table 17. Continued

Subsectors	Φ	ω	α	β	γ	GED	AIC	Log Likelihood
Health Care Providers	0.016*	-0.234***	0.108	0.972*	-0.069	1.233*	-2.363	463.416
Heavy Construction	0.006***	-0.506	0.197**	0.929*	-0.033	1.303*	-2.273	445.902
Home Construction	0.008***	-0.147	0.041	0.975*	-0.035	1.673*	-1.76	346.569
Home Improvement Retailers	0.009*	-0.416	0.137***	0.943*	0.006	1.572*	-2.555	500.419
Hotels	0.012*	-0.686**	0.243**	0.901*	-0.134**	1.161*	-2.29	449.206
Industrial Machinery	0.008*	-2.198**	0.348*	0.647*	-0.181*	1.458*	-2.624	513.818
Industrial Suppliers	0.011*	-0.63	0.156	0.904*	-0.009	1.455*	-2.531	495.886
Integrated Oil & Gas	0.006*	-2.02	0.13	0.683*	-0.149**	1.501*	-3.222	629.513
Internet	0.02*	-0.231*	0.22*	0.989*	0.056	1.213*	-1.53	217.92
Iron & Steel	0.007	-2.492*	0.039	0.489*	-0.373*	1.582*	-1.958	385.008
Marine Transportation	0.01**	-0.228**	0.1***	0.968*	-0.059***	1.401*	-1.778	350.187
Media Agencies	0.011*	-0.517**	0.26*	0.94*	-0.019	1.378*	-2.518	493.25
Medical Equipment	0.011*	-2.972*	0.155	0.528*	-0.217*	1.556*	-3.19	623.359
Medical Supplies	0.009*	-0.383***	0.141***	0.955*	-0.026	1.510*	-3.244	633.823
Mobile Telecommunications	0.014*	-0.567*	0.345*	0.938*	0.002	1.401*	-2.24	439.472
Multiutilities	0.007*	-0.831	0.124	0.883*	-0.015	1.436*	-3.495	682.375
Nondurable Household Products	0.009*	-4.334***	0.169	0.28	-0.196***	1.377*	-3.004	587.33
Nonferrous Metals	0.008**	-0.331**	0.182*	0.959*	-0.009	1.523*	-1.923	378.19
Oil Equipment & Services	0.007***	-1.902*	0.146	0.643*	-0.258*	1.655*	-2.128	417.86
Paper	0.003	-0.5**	0.192**	0.933*	-0.144*	1.439*	-2.442	478.655
Personal Products	0.012*	-5.982*	-0.148	0.001	-0.415*	1.122*	-3.291	642.987
Pharmaceuticals	0.011*	-6.357**	0.096	-0.03	-0.173***	1.449*	-3.249	634.726
Pipelines	0.01*	-0.869*	0.222**	0.883*	-0.146**	1.411*	-3.117	609.285
Platinum & Precious Metals	0.000	-1.597	2.25	-0.296	0.101	1.106*	-2.985	370.261
Publishing	0.004**	-3.125*	0.224***	0.509*	-0.396*	1.510*	-3.163	618.194
Railroads	0.012*	-0.9***	0.273**	0.877*	-0.052	1.491*	-2.792	546.287
Recreational Products	0.014*	-1.164***	0.128	0.775*	-0.199	1.243*	-1.895	237.293
Recreational Services	0.011*	-0.719**	0.214**	0.894*	-0.103**	1.468*	-2.374	465.402
Renewable Energy Equipment	0.01	-0.853	0.145	0.777***	-0.042	1.735*	-2.367	458.57
Restaurants & Bars	0.011*	0.038**	-0.011	1.005*	-0.018	1.862*	-3.032	592.772
Semiconductors	0.01**	-0.358**	0.245*	0.964*	0.004	1.494*	-1.859	365.758
Soft Drinks	0.012*	-0.261**	0.152**	0.974*	0.075***	1.180*	-3.17	619.561
Software	0.014*	-0.432*	0.302*	0.963*	0.026	1.884*	-2.24	439.531
Speciality Chemicals	0.013*	-1.289**	0.222***	0.808*	-0.14***	1.207*	-3.046	595.555
Specialized Consumer Services	0.013*	-0.586***	0.219*	0.923*	0.011	1.555*	-2.562	501.859
Specialty Retailers	0.009*	-0.626**	0.251*	0.921*	-0.095***	1.654*	-2.57	503.413
Telecommunications Equipment	0.012*	-0.434**	0.232*	0.949*	-0.039	1.639*	-2.127	417.594
Tires	0.000	-0.291**	0.154**	0.959*	-0.12*	1.323*	-1.58	311.88
Tobacco	0.018*	-7.267*	-0.238	-0.399	-0.12	1.135*	-2.528	495.324
Toys	0.009*	-1.78**	0.222	0.695*	-0.176**	1.355*	-2.445	479.126
Transportation Services	0.005	-1.452*	0.032	0.715*	-0.253*	1.460*	-2.158	423.764
Travel & Tourism	0.014*	-0.28**	0.155**	0.964*	-0.079**	1.470*	-1.505	291.29
Trucking	0.008*	-2.218	0.013	0.621**	-0.147	1.491*	-2.988	584.198
Waste & Disposal Services	0.009*	-0.219**	0.206*	0.988*	0.013	1.303*	-2.458	481.775
Water	0.009*	-0.52***	0.24*	0.94*	-0.03	1.209*	-2.878	562.912

Note: See Table 15.

In the Table 14-16, Φ and ω denote the constant terms in the mean and variance equations in the Equation (14), respectively. Moreover, α, β and γ represent the ARCH, GARCH and asymmetric leverage effects, correspondingly. The ARCH effect (α) measures the magnitude or the symmetric effect of the model. The GARCH effect (β) evaluates the persistence of current conditional volatility regardless of the market conditions. Thus, when β is relatively big, then volatility takes an extensive time to fades away subsequent a market turmoil.

The asymmetric leverage effect (γ) which first noted by Black (1976) can be defined as a tendency of negative correlation between the stock price changes and their volatility. This is known as leverage effect because when the market value of the firm with debt and equity outstanding falls (stock price falls), the firm becomes more leveraged (the debt to equity ratio increases). Accordingly, a negative γ can be considered as bad news, may have larger impact on volatility compared with a positive γ. Therefore, the leverage effect (γ) is expected to be negative.

As can be seen from Table 14-16, the GED degree parameters of the estimated models are all less than 2, which verify the point that the tails of financials, non-financials and WTI returns are heavier than the tails of standard normal distribution. Regarding the β coefficients, almost all of them are significant and relatively large which indeed imply the sluggish deterioration of the volatility shock. This also gives clear-cut evidence for the existence of the volatility clustering. For instance, the β of WTI is 0.880, which suggests that 88% of existing volatility shock can be viewed in the next period.

Moreover, the average β of the financials and non-financials are 0.83 and 0.78, respectively. This shows that volatility shocks are more persistent in the financials rather than non-financials. Also, the majority of γ coefficients are negative and significant in both financial and non-financial subsectors which imply that bad news generates more volatility than good news for these subsectors.

The residual series of the EGARCH(1,1) models for all subsectors and WTI have been investigated. Table 17-19 give the results for ARCH-LM and Ljung–Box Q^2 tests. The results of ARCH-LM test suggest that volatility clustering has wiped out from the residual series since the null hypothesis of homoscedasticity cannot be rejected for all the subsectors. Additionally, the null hypothesis of no autocorrelation also cannot be rejected for all the EGARCH estimates at 5% significance level. Therefore, it can be concluded that there are not any more volatility clustering and autocorrelation in the residual of the EGARCH estimates.

Table 18. Diagnostics tests after EGARCH estimation for the WTI

Series	ARCH-LM	P-value	$Q^2(20)$	P-value
WTI crude oil	2.401	0.121	16.484	0.686

Note: ARCH-LM is Engle's (1982) Lagrange multiplier test for the heteroscedasticity in the residual of the return series up to order 20. $Q^2(20)$ is the Ljung–Box test statistics for autocorrelation in the squared standardized residuals with 20 lags.

Table 19. Diagnostics tests after EGARCH estimation for the financials

Subsector	ARCH-LM	P-value	$Q^2(20)$	P-value
Asset Managers	0.020	0.886	10.239	0.964
Banks	0.098	0.753	7.796	0.993
Consumer Finance	0.655	0.418	7.798	0.993
Full Line Insurance	0.175	0.675	7.819	0.993
Hotel & Lodging REITs	0.487	0.485	3.996	0.997
Industrial & Office REITs	0.128	0.729	4.282	0.998
Insurance Brokers	0.056	0.811	5.632	0.999
Investment Companies	0.325	0.568	11.408	0.996
Investment Services	0.282	0.595	4.404	0.998
Life Insurance	0.243	0.621	7.623	0.994
Mortgage Finance	1.056	0.304	20.377	0.435
Mortgage REITs	0.035	0.849	11.961	0.917
Property & Casualty Insurance	0.497	0.481	13.744	0.843
Real Estate Holding & Development	0.064	0.799	13.697	0.846
Real Estate Services	0.426	0.515	23.667	0.257
Reinsurance	1.301	0.254	25.026	0.289
Residential REITs	0.263	0.654	6.746	0.997
Retail REITs	0.036	0.847	7.619	0.994
Specialty Finance	0.166	0.683	9.737	0.973
Specialty REITs	0.375	0.541	11.446	0.934

Note: See Table 18.

Table 20. Diagnostics tests after EGARCH estimation for the non-financials

Subsectors	ARCH-LM	P-value	$Q^2(20)$	P-value
Aerospace	0.446	0.504	12.804	0.886
Airlines	0.286	0.592	15.749	0.732
Alternative Electricity	1.227	0.268	20.084	0.453
Aluminum	2.300	0.130	21.479	0.369
Apparel Retailers	5.178	0.123	17.938	0.591
Auto Parts	0.036	0.849	10.294	0.963
Automobiles	0.392	0.531	22.525	0.313
Biotechnology	0.301	0.583	9.396	0.978
Brewers	0.235	0.627	20.050	0.455
Broadcasting & Entertainment	1.068	0.301	12.365	0.903
Broadline Retailers	0.005	0.942	20.879	0.404
Building Materials & Fixtures	0.605	0.437	19.770	0.472
Business Support Services	0.001	0.971	17.229	0.638
Business Training & Employment Agencies	1.835	0.176	31.443	0.059
Clothing & Accessories	0.009	0.923	23.463	0.267
Coal	0.820	0.365	27.536	0.121
Commercial Vehicles & Trucks	0.263	0.608	12.697	0.890
Commodity Chemicals	0.204	0.651	16.405	0.691
Computer Hardware	0.001	0.972	27.708	0.116
Computer Services	0.035	0.851	6.429	0.998
Consumer Electronics	0.428	0.513	5.811	0.999
Containers & Packaging	0.310	0.577	11.857	0.921
Conventional Electricity	1.487	0.223	40.847	0.056
Defense	0.285	0.593	7.569	0.994
Delivery Services	0.437	0.508	17.750	0.604
Distillers & Vintners	0.812	0.368	24.285	0.230
Diversified Industrials	0.199	0.655	7.432	0.995
Drug Retailers	0.175	0.675	17.301	0.633
Durable Household Products	0.094	0.758	11.856	0.921
Electrical Components & Equipment	0.116	0.733	17.862	0.596
Electronic Equipment	0.127	0.720	9.155	0.981
Electronic Office Equipment	0.699	0.403	16.949	0.656
Exploration & Production	0.063	0.801	24.433	0.224
Farming & Fishing	0.025	0.874	22.016	0.340
Financial Administration	0.011	0.916	25.454	0.185
Fixed Line Telecommunications	2.164	0.142	13.107	0.873
Food Products	0.584	0.445	24.381	0.226
Food Retailers & Wholesalers	0.051	0.820	22.846	0.296
Footwear	0.012	0.910	21.210	0.385
Forestry	0.816	0.368	31.206	0.253
Furnishings	0.001	0.965	11.527	0.931
Gambling	1.159	0.282	20.473	0.429
Gas Distribution	0.022	0.881	15.002	0.776
Gold Mining	0.247	0.618	10.182	0.965

Note: See Table 18.

Table 20. Continued

Subsectors	ARCH-LM	P-value	$Q^2(20)$	P-value
Health Care Providers	0.002	0.958	16.130	0.709
Heavy Construction	0.480	0.488	15.221	0.764
Home Construction	0.567	0.451	14.764	0.790
Home Improvement Retailers	0.030	0.861	8.165	0.991
Hotels	0.162	0.687	13.827	0.839
Industrial Machinery	0.009	0.923	23.228	0.278
Industrial Suppliers	0.238	0.625	11.196	0.941
Integrated Oil & Gas	0.227	0.634	30.780	0.158
Internet	0.140	0.708	18.504	0.554
Iron & Steel	0.488	0.484	18.297	0.568
Marine Transportation	2.113	0.146	20.496	0.427
Media Agencies	0.133	0.715	20.866	0.405
Medical Equipment	0.630	0.427	28.115	0.108
Medical Supplies	1.645	0.200	26.030	0.165
Mobile Telecommunications	0.847	0.357	18.028	0.586
Multiutilities	0.274	0.600	17.949	0.591
Nondurable Household Products	0.078	0.778	28.328	0.102
Nonferrous Metals	3.085	0.079	17.379	0.628
Oil Equipment & Services	0.644	0.422	18.698	0.542
Paper	0.516	0.472	10.500	0.958
Personal Products	0.020	0.886	25.485	0.131
Pharmaceuticals	0.025	0.873	21.128	0.245
Pipelines	0.571	0.450	19.262	0.505
Platinum & Precious Metals	0.783	0.377	50.327	0.568
Publishing	0.094	0.758	55.928	0.683
Railroads	0.166	0.683	13.397	0.860
Recreational Products	1.032	0.310	38.176	0.065
Recreational Services	0.028	0.866	18.451	0.558
Renewable Energy Equipment	0.402	0.527	20.246	0.443
Restaurants & Bars	1.261	0.262	24.590	0.218
Semiconductors	0.172	0.678	19.385	0.497
Soft Drinks	0.197	0.656	20.341	0.437
Software	0.615	0.433	10.953	0.947
Specialty Chemicals	0.013	0.908	8.189	0.991
Specialized Consumer Services	0.988	0.320	14.895	0.782
Specialty Retailers	0.493	0.482	11.432	0.934
Telecommunications Equipment	0.138	0.709	12.492	0.898
Tires	0.571	0.450	27.402	0.113
Tobacco	0.006	0.936	29.219	0.108
Toys	0.003	0.950	10.602	0.956
Transportation Services	0.027	0.868	18.355	0.564
Travel & Tourism	0.083	0.773	20.967	0.399
Trucking	0.017	0.895	13.039	0.876
Waste & Disposal Services	0.000	0.983	13.252	0.866
Water	0.000	0.979	14.554	0.801

Note: See Table 18.

2.4.6.2 Estimation of VaRs based on GED-EGARCH

The downside VaRs for financials, non-financials, and WTI can be obtained by means of the Eq. (16). The summary statistics of the estimated VaRs at the 95% confidence level are presented in Table 20-22. Several findings can be drawn from the outcomes in these Tables. With the exception of the one financial and two non-financial subsectors, all of the other LR statistics are less than the critical value of 3.84.

Table 21. Summary of VaRs for the WTI

Series	Mean	Std. deviation	Min.	Max.	Failure time	Failure rate	LR stat.
WTI crude oil	-0.139	0.043	-0.262	-0.061	17	0.044	0.313

Note: LR denotes to the Kupiec's (1995) likelihood ratio test. Its 95% critical value is 3.84. * indicates the inadequacy of VaR estimate.

Table 22. Summary of VaRs for the financials

Subsector	Mean	Std. deviation	Min.	Max.	Failure time	Failure rate	LR stat.
Asset Managers	-0.139	0.043	-0.262	-0.061	17	0.044	0.313
Banks	-0.094	0.047	-0.419	-0.059	20	0.052	0.023
Consumer Finance	-0.105	0.028	-0.231	-0.074	18	0.047	0.101
Full Line Insurance	-0.121	0.132	-1.256	-0.068	18	0.047	0.101
Hotel & Lodging REITs	-0.140	0.054	-0.428	-0.093	12	0.031	3.379
Industrial & Office REITs	-0.105	0.053	-0.429	-0.069	14	0.044	0.274
Insurance Brokers	-0.090	0.025	-0.249	-0.067	19	0.049	0.007
Investment Companies	-0.155	0.095	-0.624	-0.086	11	0.052	0.016
Investment Services	-0.148	0.049	-0.349	-0.076	22	0.057	0.367
Life Insurance	-0.101	0.067	-0.603	-0.051	19	0.049	0.007
Mortgage Finance	-0.144	0.089	-0.813	-0.082	20	0.052	0.023
Mortgage REITs	-0.108	0.024	-0.202	-0.071	12	0.057	0.216
Property & Casualty Insurance	-0.077	0.027	-0.193	-0.049	20	0.052	0.023
Real Estate Holding & Dev.	-0.128	0.029	-0.343	-0.104	12	0.031	3.379
Real Estate Services	-0.194	0.133	-0.848	-0.100	6	0.046	0.042
Reinsurance	-0.082	0.022	-0.170	-0.058	7	0.023	5.442*
Residential REITs	-0.091	0.027	-0.215	-0.067	21	0.054	0.144
Retail REITs	-0.086	0.045	-0.411	-0.058	12	0.031	3.379
Specialty Finance	-0.086	0.036	-0.359	-0.053	20	0.052	0.023
Specialty REITs	-0.089	0.025	-0.212	-0.063	19	0.049	0.007

Note: See Table 21.

Table 23. Summary of VaRs for the non-financials

Subsector	Mean	Std. deviation	Min.	Max.	Failure time	Failure rate	LR stat.
Aerospace	-0.089	0.030	-0.221	-0.053	21	0.054	0.144
Airlines	-0.140	0.041	-0.458	-0.114	21	0.054	0.144
Alternative Electricity	-0.092	0.028	-0.225	-0.065	17	0.049	0.010
Aluminum	-0.152	0.048	-0.559	-0.115	14	0.036	1.716
Apparel Retailers	-0.134	0.053	-0.571	-0.085	20	0.052	0.023
Auto Parts	-0.095	0.040	-0.459	-0.064	20	0.052	0.023
Automobiles	-0.139	0.053	-0.512	-0.095	15	0.039	1.112
Biotechnology	-0.132	0.052	-0.270	-0.064	19	0.049	0.003
Brewers	-0.093	0.008	-0.099	0.009	11	0.028	4.463*
Broadcasting & Entertainment	-0.116	0.042	-0.230	-0.047	18	0.047	0.101
Broadline Retailers	-0.091	0.027	-0.338	-0.068	22	0.057	0.367
Building Materials & Fixtures	-0.104	0.027	-0.268	-0.066	22	0.057	0.367
Business Support Services	-0.084	0.019	-0.160	-0.060	22	0.057	0.367
Business Train. & Emp. Agencies	-0.131	0.035	-0.280	-0.085	11	0.038	0.868
Clothing & Accessories	-0.115	0.045	-0.391	-0.077	26	0.067	2.182
Coal	-0.172	0.034	-0.304	-0.117	23	0.059	0.685
Commercial Vehicles & Trucks	-0.119	0.033	-0.382	-0.078	20	0.052	0.023
Commodity Chemicals	-0.094	0.027	-0.259	-0.059	19	0.049	0.007
Computer Hardware	-0.112	0.030	-0.277	-0.064	13	0.034	2.468
Computer Services	-0.088	0.016	-0.200	-0.073	16	0.041	0.647
Consumer Electronics	-0.212	0.017	-0.275	-0.126	16	0.047	0.069
Containers & Packaging	-0.091	0.028	-0.281	-0.027	22	0.057	0.367
Conventional Electricity	-0.065	0.013	-0.115	-0.039	28	0.072	3.598
Defense	-0.088	0.035	-0.245	-0.037	17	0.044	0.313
Delivery Services	-0.121	0.034	-0.225	-0.070	21	0.054	0.144
Distillers & Vintners	-0.095	0.037	-0.369	-0.062	17	0.044	0.313
Diversified Industrials	-0.086	0.035	-0.252	-0.054	17	0.044	0.313
Drug Retailers	-0.095	0.029	-0.271	-0.057	24	0.062	1.096
Durable Household Products	-0.109	0.060	-0.524	-0.067	16	0.041	0.647
Electrical Comp. & Equipment	-0.093	0.035	-0.398	-0.071	18	0.047	0.101
Electronic Equipment	-0.116	0.053	-0.350	-0.059	23	0.059	0.685
Electronic Office Equipment	-0.122	0.048	-0.337	-0.067	18	0.047	0.101
Exploration & Production	-0.108	0.030	-0.326	-0.080	25	0.065	1.596
Farming & Fishing	-0.126	0.058	-0.588	-0.092	9	0.052	0.011
Financial Administration	-0.079	0.027	-0.239	-0.051	21	0.054	0.144
Fixed Line Telecommunications	-0.081	0.023	-0.210	-0.058	23	0.059	0.685
Food Products	-0.062	0.021	-0.147	-0.029	18	0.047	0.101
Food Retailers & Wholesalers	-0.078	0.012	-0.206	-0.033	15	0.039	1.112
Footwear	-0.142	0.046	-0.284	-0.071	22	0.057	0.367
Forestry	-0.102	0.038	-0.224	-0.045	6	0.069	0.592
Furnishings	-0.116	0.035	-0.314	-0.086	18	0.047	0.101
Gambling	-0.161	0.042	-0.431	-0.119	22	0.057	0.367
Gas Distribution	-0.083	0.035	-0.281	-0.061	16	0.041	0.647
Gold Mining	-0.172	0.022	-0.308	-0.146	17	0.044	0.313

Note: See Table 21.

Table 23. Continued

Subsector	Mean	Std. deviation	Min.	Max.	Failure time	Failure rate	LR stat.
Health Care Providers	-0.118	0.028	-0.317	-0.079	23	0.059	0.685
Heavy Construction	-0.126	0.029	-0.294	-0.089	20	0.052	0.023
Home Construction	-0.159	0.010	-0.202	-0.104	17	0.044	0.313
Home Improvement Retailers	-0.102	0.017	-0.159	-0.075	18	0.047	0.101
Hotels	-0.128	0.048	-0.333	-0.081	17	0.044	0.313
Industrial Machinery	-0.101	0.034	-0.406	-0.067	15	0.039	1.112
Industrial Suppliers	-0.104	0.016	-0.188	-0.075	16	0.041	0.647
Integrated Oil & Gas	-0.072	0.010	-0.142	-0.060	17	0.044	0.313
Internet	-0.173	0.075	-0.372	-0.052	17	0.061	0.705
Iron & Steel	-0.147	0.042	-0.489	-0.079	23	0.059	0.685
Marine Transportation	-0.163	0.035	-0.304	-0.116	22	0.057	0.367
Media Agencies	-0.166	0.015	-0.209	0.008	5	0.013	15.720*
Medical Equipment	-0.072	0.017	-0.220	-0.058	20	0.052	0.023
Medical Supplies	-0.069	0.012	-0.112	-0.051	22	0.057	0.367
Mobile Telecommunications	-0.134	0.061	-0.364	-0.059	21	0.054	0.144
Multiutilities	-0.065	0.006	-0.101	-0.056	22	0.057	0.367
Nondurable Household Products	-0.081	0.021	-0.361	-0.026	23	0.059	0.685
Nonferrous Metals	-0.149	0.037	-0.303	-0.093	22	0.057	0.367
Oil Equipment & Services	-0.134	0.038	-0.415	-0.092	19	0.049	0.007
Paper	-0.119	0.054	-0.527	-0.079	22	0.057	0.367
Personal Products	-0.073	0.015	-0.182	-0.013	14	0.036	1.716
Pharmaceuticals	-0.069	0.011	-0.101	-0.049	25	0.065	1.596
Pipelines	-0.082	0.036	-0.306	-0.048	20	0.052	0.023
Platinum & Precious Metals	-0.334	0.215	-0.966	0.000	4	0.010	3.341
Publishing	-0.080	0.030	-0.332	-0.054	14	0.036	1.716
Railroads	-0.092	0.026	-0.274	-0.058	19	0.049	0.007
Recreational Products	-0.145	0.038	-0.331	-0.070	14	0.057	0.267
Recreational Services	-0.115	0.034	-0.341	-0.087	26	0.067	2.182
Renewable Energy Equipment	-0.308	0.026	-0.383	-0.280	5	0.050	0.001
Restaurants & Bars	-0.083	0.023	-0.111	-0.030	19	0.049	0.007
Semiconductors	-0.155	0.051	-0.304	-0.067	18	0.047	0.101
Soft Drinks	-0.076	0.023	-0.145	-0.041	19	0.049	0.007
Software	-0.123	0.057	-0.280	-0.040	18	0.047	0.101
Specialty Chemicals	-0.081	0.027	-0.261	-0.041	17	0.044	0.313
Specialized Consumer Services	-0.102	0.027	-0.212	-0.072	20	0.052	0.023
Specialty Retailers	-0.102	0.032	-0.258	-0.064	20	0.052	0.023
Telecommunications Equipment	-0.134	0.047	-0.371	-0.076	18	0.047	0.101
Tires	-0.192	0.073	-0.492	-0.110	20	0.052	0.023
Tobacco	-0.104	0.024	-0.181	-0.047	21	0.054	0.144
Toys	-0.114	0.034	-0.483	-0.096	20	0.052	0.023
Transportation Services	-0.134	0.033	-0.374	-0.063	21	0.054	0.144
Travel & Tourism	-0.181	0.053	-0.374	-0.113	17	0.045	0.208
Trucking	-0.082	0.010	-0.145	0.000	18	0.047	0.101
Waste & Disposal Services	-0.120	0.046	-0.271	-0.046	17	0.044	0.313
Water	-0.089	0.024	-0.180	-0.051	17	0.044	0.313

Note: See Table 21.

Thus, by the Kupiec's (1995) backtest approach, it can be concluded that the EGARCH(1,1) model has sufficiently estimated the VaRs at the 95% confidence level for the 107 out of 110 return series. The model was unable to adequately estimate the VaRs for the Reinsurance, Brewers and Media Agencies subsectors. From Table 20, it can be seen that on average, the maximum monthly loss for the WTI crude oil is not more than 13.9% with 95% probability. In other words, there is a 5% possibility that the average monthly loss for the WTI may exceed 13.9%. The average of estimated VaRs for the financials and non-financials are -0.1141 and -0.1174, respectively. This shows that on average, they both nearly experience the same level of risk. Additionally, it can be drawn from the results that the VaR estimates of non-financials are more precise than those of the financials as the average LR statistics of the former is 0.7371 and that of the latter is 0.8632.

According to the estimated VaRs, the top-five riskiest financial subsectors are Real Estate Services (-19.4%), Investment Companies (-15.5%), Investment Services (-14.8%), Mortgage Finance (-14.4%), and Hotel & Lodging REITs (-14.0%). On the other side, Platinum & Precious Metals (-33.4%), Renewable Energy Equipment (-30.8%), Consumer Electronics (-21.2%), Tires (-19.2%), and Travel & Tourism (-18.1%) are the top-five riskiest non-financial subsectors. Moreover, the least risky financial subsector is Property & Casualty Insurance (-7.7%) and the least risky non-financial subsector is Food Products (-6.2%). Figure 16 and 17 exhibit the top-five riskiest financial and non-financial subsectors. Interestingly, for almost all the subsectors, the VaRs fail to estimate the maximum amount of risk during the U.S. recessions (shaded areas) especially throughout the 2008-2009 crisis. As a result, the subsectors' negative returns exceed the VaR estimates during these periods.

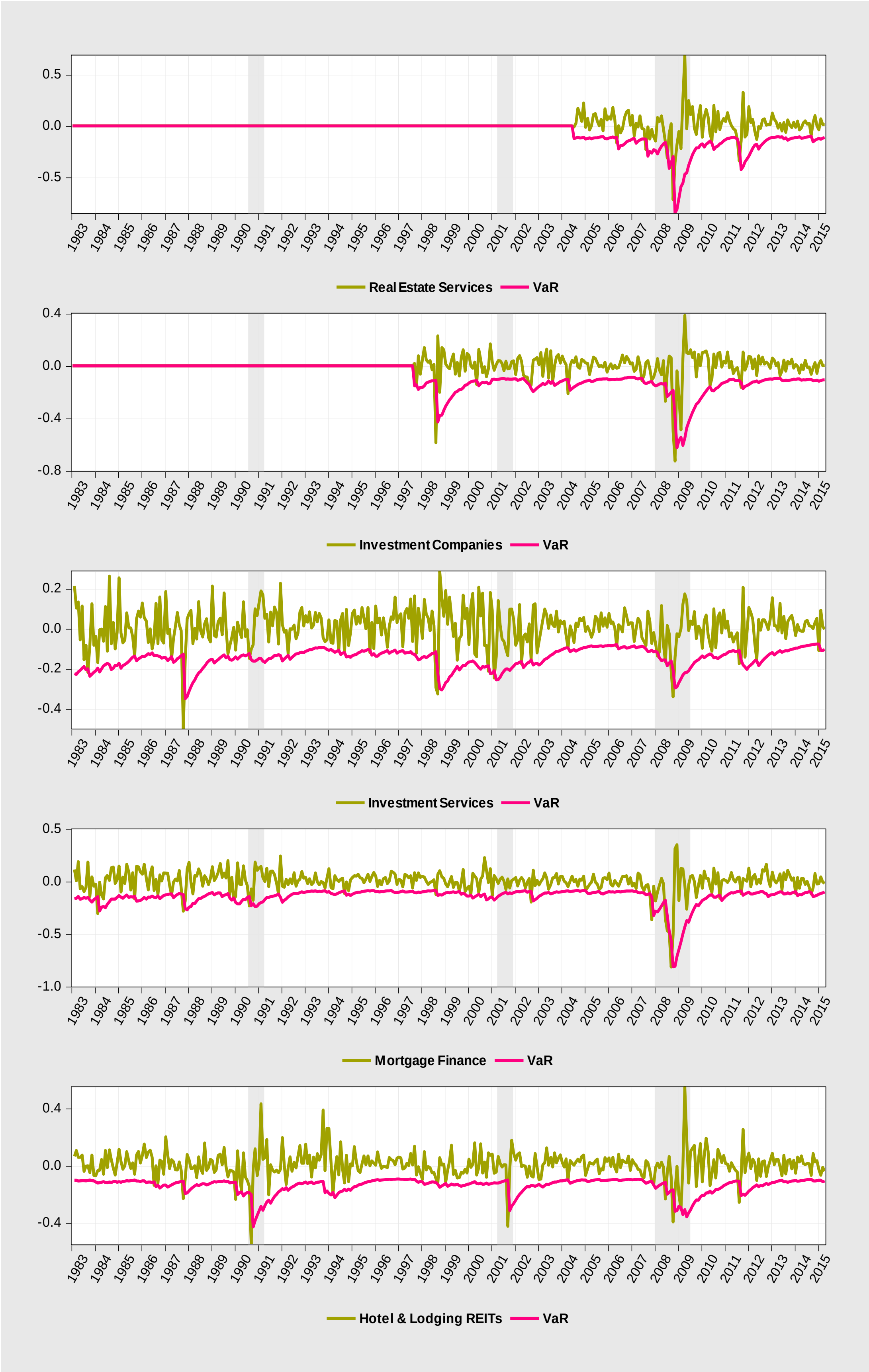


Figure 16. VaR estimations for the top-five riskiest financial subsectors

Figure 17. VaR estimations for the top-five riskiest non-financial subsectors

2.4.6.3 Risk Spillover Test from WTI to Subsectors

For testing the risk spillover between WTI and the subsectors' returns, the causal interactions between them should be inspected. With this respect, the aforesaid methodology of Hill's (2007) time-varying causality will be employed here. This is a bivariate test where causality between two different time series is measured. The length rolling window is fixed at 60 months and the maximum order of the VAR model is 4 lags. As it is explained before, instead of using the oil and subsectors' returns in the model, their estimated VaRs will be used to test the risk spillover from crude oil market to the subsectors. Hence, the aim is to check the null hypothesis of non-causality running from WTI to the subsectors' returns. Causality takes place at any horizon if and only if it takes place at horizon 1 (first month in each window).

Table 24. Time-varying causality in risk for financial subsectors

Null hypothesis (H_0)	Avg. VAR order	Avg. BPV	Rejection rate of H_0
Oil ↛ Asset Managers	1.8777	0.5023	10.7034
Oil ↛ Banks	2.1009	0.3895	25.0765
Oil ↛ Consumer Finance	1.6177	0.5324	8.8685
Oil ↛ Full Line Insurance	1.8966	0.3908	27.5862
Oil ↛ Hotel & Lodging REITs	1.9419	0.3552	24.4648
Oil ↛ Industrial & Office REITs	1.8731	0.4339	18.8462
Oil ↛ Insurance Brokers	1.8960	0.3214	35.4740
Oil ↛ Investment Companies	4.0000	0.5825	9.3750
Oil ↛ Investment Services	1.9052	0.4516	16.2080
Oil ↛ Life Insurance	1.9939	0.3601	26.6055
Oil ↛ Mortgage Finance	4.0000	0.5673	24.2604
Oil ↛ Mortgage REITs	4.0000	0.4450	12.6316
Oil ↛ Property & Casualty Insurance	1.8471	0.4264	15.5963
Oil ↛ Real Estate Holding & Development	1.9021	0.3822	11.6208
Oil ↛ Real Estate Services	4.0000	0.4092	10.9091
Oil ↛ Reinsurance	1.6849	0.3746	9.6639
Oil ↛ Residential REITs	1.7920	0.4822	19.2661
Oil ↛ Retail REITs	1.7890	0.5176	12.5382
Oil ↛ Specialty Finance	1.7309	0.4523	15.9021
Oil ↛ Specialty REITs	1.9939	0.3312	31.8043

Notes: ↛ denotes the non-causality null hypothesis. VAR denotes Vector Autoregressive model and BPV denotes the bootstrap P-values. The maximum order of VAR model is 4 lags. Size of the fixed rolling-window is 60 months. Bootstrap iterations are 1000 times. BPV of less than 5% indicates causality within that window.

Table 25. Time-varying causality in risk for non-financial subsectors

Null hypothesis (H_0)			Avg. VAR order	Avg. BPV	Rejection rate of H_0
Oil	$\nrightarrow$	Aerospace	1.7554	0.3998	24.1590
Oil	$\nrightarrow$	Airlines	1.4893	0.2606	30.5810
Oil	$\nrightarrow$	Alternative Electricity	2.0000	0.4641	20.3448
Oil	$\nrightarrow$	Aluminum	1.9969	0.3299	25.6881
Oil	$\nrightarrow$	Apparel Retailers	1.7134	0.5493	3.0488
Oil	$\nrightarrow$	Auto Parts	1.9238	0.3455	35.9756
Oil	$\nrightarrow$	Automobiles	1.7012	0.4504	14.0244
Oil	$\nrightarrow$	Biotechnology	1.8720	0.4285	9.7561
Oil	$\nrightarrow$	Brewers	1.7165	0.4370	23.4756
Oil	$\nrightarrow$	Broadcasting & Entertainment	1.9052	0.6050	0.3058
Oil	$\nrightarrow$	Broadline Retailers	1.8140	0.3196	35.3659
Oil	$\nrightarrow$	Building Materials & Fixtures	1.9419	0.3999	10.7034
Oil	$\nrightarrow$	Business Support Services	1.6128	0.5110	6.0976
Oil	$\nrightarrow$	Business Training & Employment Agencies	1.5627	0.5228	8.8685
Oil	$\nrightarrow$	Clothing & Accessories	1.6402	0.3706	18.5976
Oil	$\nrightarrow$	Coal	1.7095	0.4732	11.9266
Oil	$\nrightarrow$	Commercial Vehicles & Trucks	1.9085	0.5108	1.8293
Oil	$\nrightarrow$	Commodity Chemicals	1.8720	0.4022	16.4634
Oil	$\nrightarrow$	Computer Hardware	1.6341	0.5778	3.9634
Oil	$\nrightarrow$	Computer Services	1.5902	0.4945	6.4220
Oil	$\nrightarrow$	Consumer Electronics	1.6477	0.5283	9.2527
Oil	$\nrightarrow$	Containers & Packaging	1.9205	0.4156	22.9358
Oil	$\nrightarrow$	Conventional Electricity	2.0153	0.2412	34.5566
Oil	$\nrightarrow$	Defense	1.6239	0.3825	22.3242
Oil	$\nrightarrow$	Delivery Services	1.9626	0.4105	11.2805
Oil	$\nrightarrow$	Distillers & Vintners	1.8598	0.5298	8.8415
Oil	$\nrightarrow$	Diversified Industrials	1.9207	0.4149	22.8659
Oil	$\nrightarrow$	Drug Retailers	1.6982	0.4449	11.2805
Oil	$\nrightarrow$	Durable Household Products	1.7805	0.3940	21.3415
Oil	$\nrightarrow$	Electrical Components & Equipment	1.6098	0.3996	15.8537
Oil	$\nrightarrow$	Electronic Equipment	1.6646	0.5470	13.4146
Oil	$\nrightarrow$	Electronic Office Equipment	1.7095	0.4309	19.5719
Oil	$\nrightarrow$	Exploration & Production	1.7370	0.5856	4.5872
Oil	$\nrightarrow$	Farming & Fishing	4.0000	0.5297	6.4935
Oil	$\nrightarrow$	Financial Administration	1.6829	0.4932	4.8780
Oil	$\nrightarrow$	Fixed Line Telecommunications	1.6422	0.5371	3.0581
Oil	$\nrightarrow$	Food Products	1.6677	0.4090	17.3780
Oil	$\nrightarrow$	Food Retailers & Wholesalers	1.5183	0.5102	6.4024
Oil	$\nrightarrow$	Footwear	1.4512	0.3265	28.9634
Oil	$\nrightarrow$	Forestry	4.0000	0.3694	14.9254
Oil	$\nrightarrow$	Furnishings	2.2012	0.3195	37.5001
Oil	$\nrightarrow$	Gambling	1.7982	0.3709	16.2080
Oil	$\nrightarrow$	Gas Distribution	1.9083	0.4562	11.6208
Oil	$\nrightarrow$	Gold Mining	1.4220	0.4818	14.6789

Note: See Table 24.

Table 25. Continued

Null hypothesis (H_0)		Avg. VAR order	Avg. BPV	Rejection rate of H_0
Oil $\nrightarrow$	Health Care Providers	1.5152	0.5087	7.9268
Oil $\nrightarrow$	Heavy Construction	1.5199	0.4267	16.5138
Oil $\nrightarrow$	Home Construction	1.7195	0.3879	5.4878
Oil $\nrightarrow$	Home Improvement Retailers	1.6402	0.4232	12.1951
Oil $\nrightarrow$	Hotels	1.5810	0.3419	15.9021
Oil $\nrightarrow$	Industrial Machinery	1.7805	0.4063	30.1829
Oil $\nrightarrow$	Industrial Suppliers	1.6860	0.5459	8.5366
Oil $\nrightarrow$	Integrated Oil & Gas	1.4557	0.5187	9.1743
Oil $\nrightarrow$	Internet	4.0000	0.5054	11.6732
Oil $\nrightarrow$	Iron & Steel	1.7645	0.4279	20.4893
Oil $\nrightarrow$	Marine Transportation	1.8994	0.4597	4.2683
Oil $\nrightarrow$	Media Agencies	2.0457	0.4345	6.6788
Oil $\nrightarrow$	Medical Equipment	1.6616	0.5454	5.4878
Oil $\nrightarrow$	Medical Supplies	1.7348	0.3800	23.1707
Oil $\nrightarrow$	Mobile Telecommunications	1.6086	0.4050	10.0917
Oil $\nrightarrow$	Multiutilities	1.9939	0.2473	40.3670
Oil $\nrightarrow$	Nondurable Household Products	1.5793	0.3901	28.3537
Oil $\nrightarrow$	Nonferrous Metals	1.7278	0.3638	16.8196
Oil $\nrightarrow$	Oil Equipment & Services	1.5994	0.4254	15.2905
Oil $\nrightarrow$	Paper	1.8991	0.3762	31.1927
Oil $\nrightarrow$	Personal Products	1.6098	0.4758	15.2439
Oil $\nrightarrow$	Pharmaceuticals	1.8994	0.4147	25.0000
Oil $\nrightarrow$	Pipelines	1.9807	0.4657	7.8768
Oil $\nrightarrow$	Platinum & Precious Metals	1.5924	0.4914	2.1739
Oil $\nrightarrow$	Publishing	1.7768	0.4287	29.3578
Oil $\nrightarrow$	Railroads	1.6494	0.4985	13.1098
Oil $\nrightarrow$	Recreational Products	2.2390	0.4004	21.6355
Oil $\nrightarrow$	Recreational Services	1.7615	0.3947	24.7706
Oil $\nrightarrow$	Renewable Energy Equipment	4.0000	0.4451	16.0494
Oil $\nrightarrow$	Restaurants & Bars	1.5657	0.4978	12.5382
Oil $\nrightarrow$	Semiconductors	1.6128	0.6064	4.2683
Oil $\nrightarrow$	Soft Drinks	1.7744	0.4477	14.0244
Oil $\nrightarrow$	Software	1.7982	0.4891	5.5046
Oil $\nrightarrow$	Specialty Chemicals	1.5627	0.5183	7.0336
Oil $\nrightarrow$	Specialized Consumer Services	1.5366	0.5460	15.2439
Oil $\nrightarrow$	Specialty Retailers	1.5535	0.5466	5.8104
Oil $\nrightarrow$	Telecommunications Equipment	1.6758	0.5863	12.2324
Oil $\nrightarrow$	Tires	1.5335	0.4219	6.7073
Oil $\nrightarrow$	Tobacco	1.4573	0.5050	18.9024
Oil $\nrightarrow$	Toys	1.5000	0.5107	3.3537
Oil $\nrightarrow$	Transportation Services	1.9268	0.2592	34.4512
Oil $\nrightarrow$	Travel & Tourism	1.4832	0.2733	37.3089
Oil $\nrightarrow$	Trucking	1.4634	0.3746	20.1220
Oil $\nrightarrow$	Waste & Disposal Services	2.2591	0.3887	20.4268
Oil $\nrightarrow$	Water	1.5291	0.4343	11.9266

Note: See Table 24.

Table 23 and 24 display the time-varying causality in risk for the financial and non-financial subsectors, respectively. For the financials, the rejection rate of null hypothesis implying time-varying non-causality in risk ranges from 8.87% (Consumer Finance) to 35.47% (Insurance Brokers). This means that, for instance, there is a risk spillover effect from oil to Insurance Brokers in 35.47% of the time. For the non-financials, the rejection rate of null hypothesis implying time-varying non-causality in risk ranges from 0.30% (Broadcasting & Entertainment) to 40.37% (Multiutilities). This means that, for example, 0.30% and 40.37% of risk from the oil market spillover to Broadcasting & Entertainment and Multiutilities subsectors during the time span of the study, accordingly. This result is very compelling as the former subsector has almost no dependence on the oil but the latter subsector has a heavy reliance on the oil as it is the main input in their production process.

Figure 18 and 19 show the financial and non-financial subsectors which accept the highest level of risk spillover from crude oil. Among the financials, Insurance Brokers, Specialty REITs, Full Line Insurance, Life Insurance, and Banks are the subsectors receiving the highest causality in risk from the oil market. For the non-financials, Multiutilities, Furnishings, Travel & Tourism, Broadline Retailers, and Auto Parts are the subsectors which receive the highest level of risk spillover effect from the crude oil market during the period of the study. The recessionary periods in the U.S. are highlighted in gray in these Figures. Remarkably, during and after the 2008-09 financial crisis, there are high levels of risk spillover effect running from the oil market toward financial and non-financial subsectors as the bootstrap p-values fall below 5%. Among the financials, the most continuous risk spillover effect occurs for Insurance Brokers starting from mid-2007 to mid-2013.

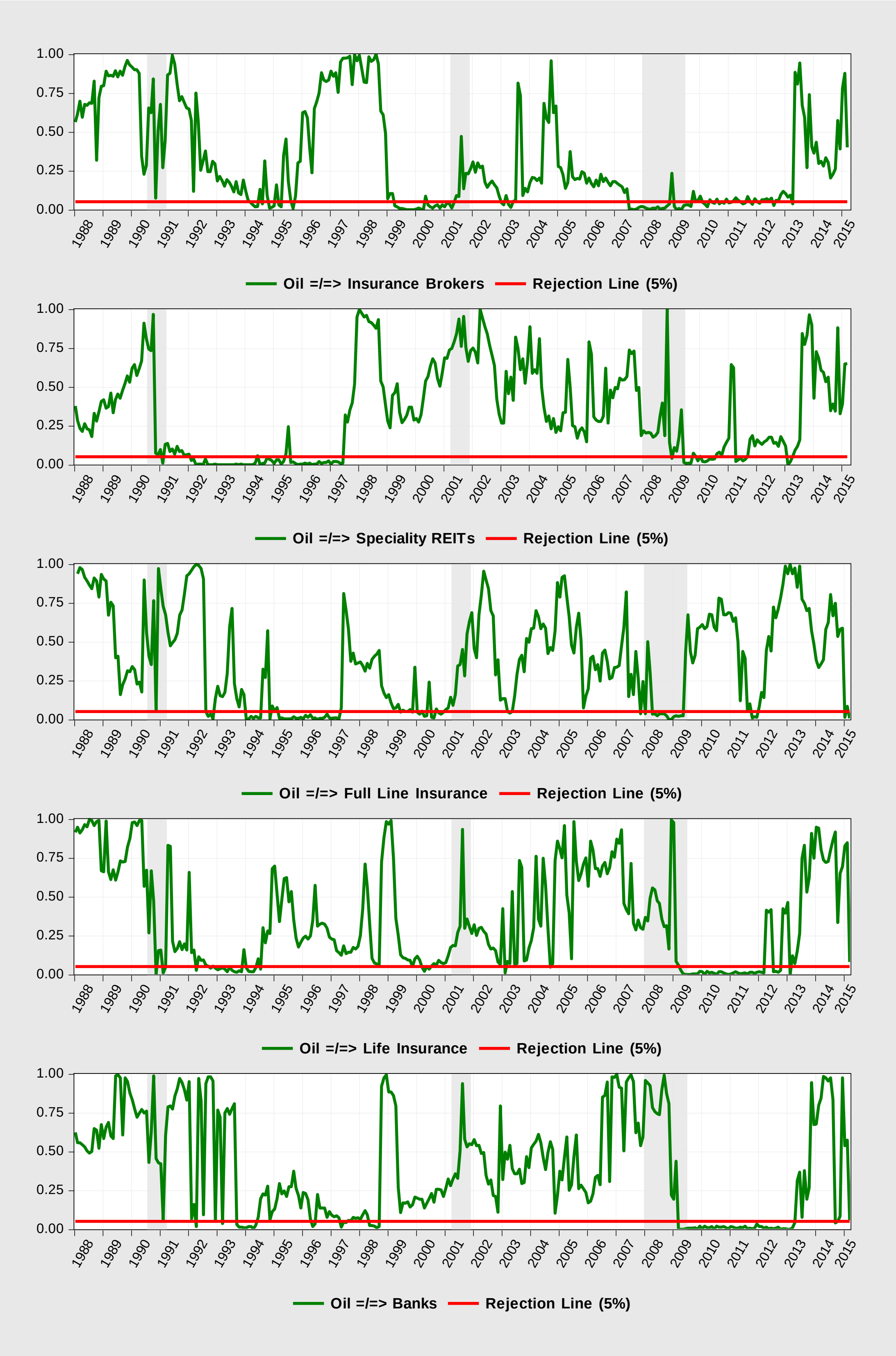


Figure 18. Time-varying causality in risk for the top-five financial subsectors

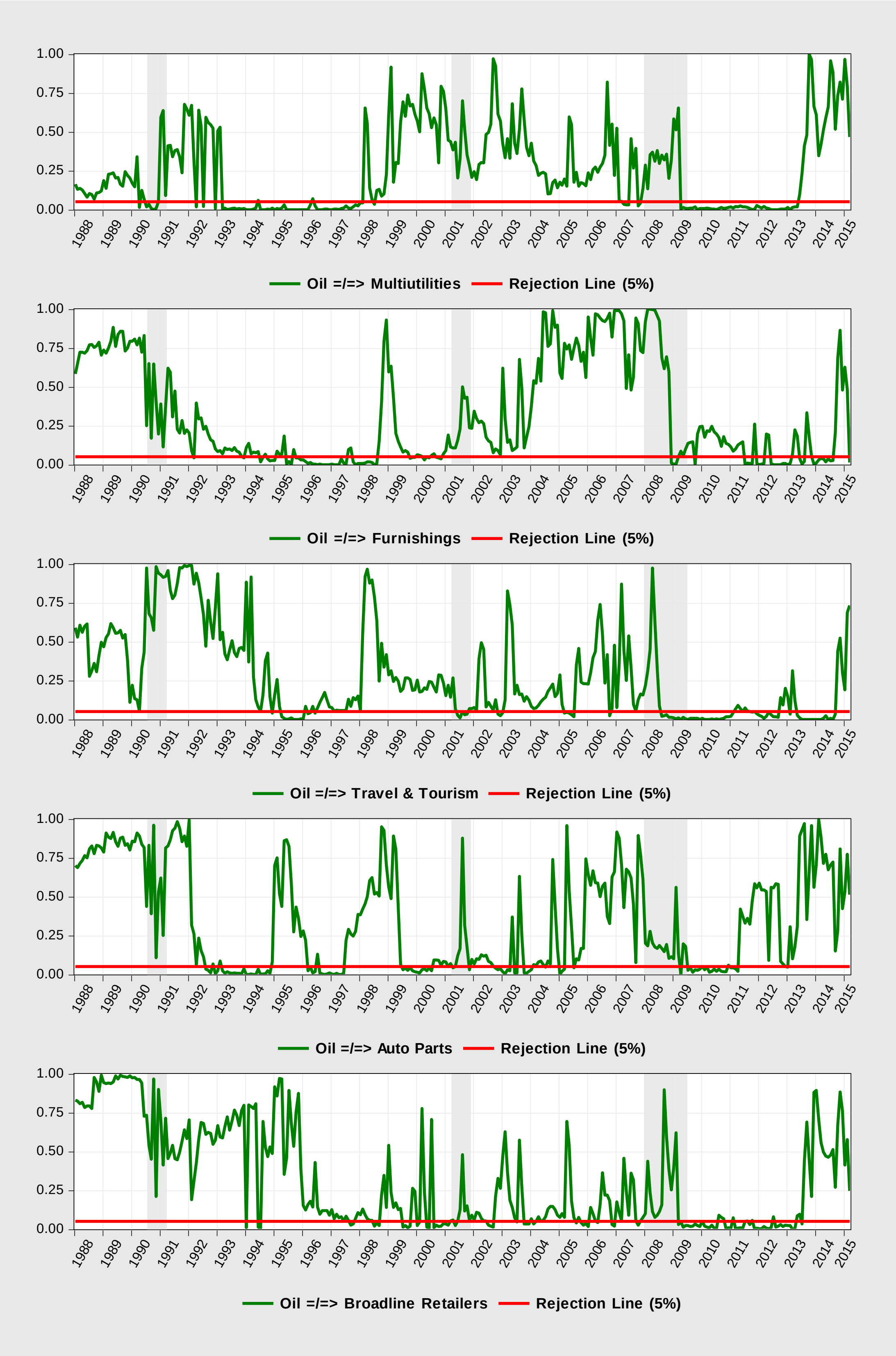


Figure 19. Time-varying causality in risk for the top-five non-financial subsectors

For the non-financials, the most continuous risk spillover effect happens for Travel & Tourism starting from mid-2008 to mid-2014 (with exception of few months). Overall, it can be inferred that the risk from the crude oil market tends to spill over to the above markets mainly during financial crisis periods. Furthermore, during the 1990s, some of the subsectors such as Specialty REITs, Full Line Insurance, Life Insurance, Multiutilities, Furnishings, and Auto Parts, experience the risk spillover from the crude oil market. It may be due to the impacts of the U.S. recession in the early 1990s and the 1990 oil price shock subsequent of Iraq's invasion of Kuwait which doubled the oil price from July to October, 1990.

2.5 Conclusion

This study investigates the oil price risk exposure of the financial and non-financial subsectors in the U.S. stock markets over the period from January 1983 to March 2015. In these estimates, the existence of structural breaks in the equity returns of the industry subsectors is taken into account. The Bai and Perron (2003) approach is used to identify multiple breakpoints. By employing the Fama and French (2015) five-factor asset pricing model integrated with oil price risk factor, the oil price risk exposures of the financial and non-financial industries are estimated.

Given the heterogeneity in the oil price risk exposure of different industries, this study measures the effect of oil price risk on all U.S. industries at the subsector level because an industry-level study may conceal important subsector effects. The results show that majority of financial and non-financial subsectors are affected by oil price changes, but the magnitude of the impact appears to be rather limited. The size of oil price sensitivity differs noticeably across subsectors and over time.

Evidently, some industries have experienced substantial changes in oil price exposure throughout the period of the study. For example, the oil price risk exposure of some subsectors is low in the pre-break period but becomes higher and more significant in the post-break period. The financial subsectors that display this behavior are Banks, Full Line Insurance, Investment Services, Mortgage Finance, Specialty Finance, and Specialty REITs. The non-financial subsectors that display similar behavior are Airlines, Coal, Exploration & Production, Furnishings, Gambling, Gold Mining, Heavy Construction, Nonferrous Metals, and Integrated Oil & Gas. This pattern-changing behavior may be caused by various important milestones, such as the early-1990s recession in the U.S., the Asian and Russian financial crises of 1997–1998, the U.S. invasion of Iraq in 2003 followed by the oil price doubling from mid-2003 to late 2005, and the U.S. sub-prime mortgage crisis of 2007.

Moreover, it is shown that majority of financial subsectors are affected negatively, and most of the non-financial subsectors are affected positively, by oil prices. Furthermore, the magnitude of the impact of oil prices on the financial subsectors is much lower than the magnitude of their impact on the non-financial subsectors. Among the financial subsectors, Mortgage Finance and Real Estate Services have the largest negative and positive exposures to the oil price risk, respectively. For the non-financial subsectors, Airlines and Oil Equipment Services have the largest negative and positive oil price risk exposures, respectively. Furthermore, it is shown that MKT, SMB and HML which are the risk factors in the FF3F model have relatively higher role in explaining the returns for the financial subsectors than those for the non-financial subsectors.

Interestingly, the recently introduced Fama-French risk factors, RMW and CMA, along with OIL, play more important role in determining the equity returns for the non-financial subsectors than those for the financial subsectors. For the both types of subsectors, the monthly return on the market portfolio (MKT), which is calculated as the value-weighted return of all CRSP stocks incorporated in the U.S. in excess of the 1-month Treasury bill rate, has the highest share among other risk factors in determining the subsectors' returns.

The second most important risk factor for the financials, HML, is the monthly return of a portfolio with high book-to-market ratio (a value portfolio) in excess of a portfolio with low book-to-market ratio (growth portfolio) which suggests the important role of book-to-market ratio in asset valuation of financial stocks. The second most important risk factor for the non-financials, CMA, is the monthly return of a portfolio with conservative investment strategies in excess of a portfolio with aggressive investment strategies. This indicates the importance of CMA in pricing non-financial stocks.

However, the monthly return on West Texas Intermediate crude oil (OIL) has the least important role in explaining the subsectors' returns for the both financials and non-financials. Additionally, via the analysis of time-varying causality in return, the subsectors which receive the highest level of return spillover from crude oil have been identified. Among the financials, Full Line Insurance, Life Insurance, Banks, Hotel & Lodging REITs, and Residential REITs are the top subsectors receiving highest causality in return from crude oil market.

For the non-financials, Auto Parts, Electronic Office Equipment, Tires, Furnishings, and Commodity Chemicals are the top subsectors which receive the highest level of return spillover from crude oil during the period of the study. It is pointed out that after the 1990-91 and 2008-09 recessions, there are high levels of causality in return running from oil market to financial and non-financial subsectors. This may be due to the higher demand and more dependency on oil during the expansionary phase of the economic cycle. Nonetheless, this is not often the case for the 2001 recession perhaps because it was very short-lived and shallow. By the help of the GED shape parameters in the estimated EGARCH(1,1) models, it is has been verified that the tails of financials, non-financials and WTI returns are heavier than the tails of standard normal distribution.

These results justify the use this type of distribution here. The results also show that investors should not ignore the tail risk as they are very costly when they occur (Rajan, 2010). Based on the estimated results of the EGARCH(1,1), it can be suggested that volatility persistence is relatively high for almost all of the subsectors and WTI. This indicates that volatility shocks decay calmly and it also gives explicit evidence for the existence of the volatility clustering. Moreover, the average β of the financials and non-financials are 0.83 and 0.78, respectively.

This shows that volatility shocks are more persistent in the financials rather than non-financials. In testing the leverage effect, it is revealed that the majority of γ coefficients are negative and significant in both financial and non-financial subsectors which indicate that bad news generates more volatility than good news for these subsectors.

Furthermore, by the help of the Kupiec's (1995) backtest method, it is proved that the EGARCH(1,1) model has sufficiently estimated the VaRs at the 95% confidence level for the 107 out of 110 return series. It can be seen from the results that on average, the maximum monthly loss for the WTI crude oil is not more than 13.9% with 95% probability. In other words, there is a 5% possibility that the average monthly loss for the WTI may exceed 13.9%. The average of estimated VaRs for the financials and non-financials are -0.1141 and -0.1174, respectively. This shows that on average, they both have approximately the same level of risk.

Another finding is that the VaR estimates of non-financials are more precise than those of the financials as the average LR statistics of the former is 0.7371 and that of the latter is 0.8632. This means that modeling the risk for the financials is more difficult than that of the non-financials. According to the estimated VaRs, the top-five riskiest financial subsectors are Real Estate Services (-19.4%), Investment Companies (-15.5%), Investment Services (-14.8%), Mortgage Finance (-14.4%), and Hotel & Lodging REITs (-14.0%). On the other side, Platinum & Precious Metals (-33.4%), Renewable Energy Equipment (-30.8%), Consumer Electronics (-21.2%), Tires (-19.2%), and Travel & Tourism (-18.1%) are the top-five riskiest non-financial subsectors.

Moreover, the least risky financial subsector is Property & Casualty Insurance (-7.7%) and the least risky non-financial subsector is Food Products (-6.2%). It should be noted that for almost all the subsectors, the VaRs are unable to effectively define the maximum amount of risk during the U.S. recessions especially throughout the 2008-2009 crisis.

As a result, the subsectors' negative returns exceed the VaR estimates during these periods. Thus, there is really a need for developing a new technique in order to overcome the shortcomings of VaR method during crisis periods. Through the use of VaRs and the Hill's (2007) time-varying causality, the risk spillover from WTI to the financial and non-financial subsectors have examined. For the financials, the rejection rate of null hypothesis implying time-varying non-causality in risk ranges from 8.87% (Consumer Finance) to 35.47% (Insurance Brokers). This implies that, for instance, there is a risk spillover effect from oil to Insurance Brokers in 35.47% of the time.

For the non-financials, the rejection rate of null hypothesis implying time-varying non-causality in risk ranges from 0.30% (Broadcasting & Entertainment) to 40.37% (Multiutilities). This means that, for example, 0.30% and 40.37% of risk from the oil market spillover to Broadcasting & Entertainment and Multiutilities subsectors during the time span of the study, accordingly. This result is very convincing as the former subsector has almost no dependence on the oil but the latter subsector has a heavy dependence on the oil as it is the main input in their production process.

Among the financial, Insurance Brokers, Specialty REITs, Full Line Insurance, Life Insurance, and Banks are the subsectors receiving the highest causality in risk from the oil market. For the non-financials, Multiutilities, Furnishings, Travel & Tourism, Broadline Retailers, and Auto Parts are the subsectors which receive the highest level of risk spillover effect from the crude oil market during the period of the study.

It is found that during and after the 2008-09 financial crisis, there are high levels of risk spillover effect running from the oil market toward financial and non-financial subsectors as the bootstrap p-values fall below 5%. Among the financials, the most continuous risk spillover effect occurs for Insurance Brokers starting from mid-2007 to mid-2013.

For the non-financials, the most continuous risk spillover effect happens for Travel & Tourism starting from mid-2008 to mid-2014 (with exception of few months). Overall, it can be concluded that the risk from the crude oil market tends to be transferred to these markets mainly in the course of financial crisis periods. In addition, during the 1990s, some of the subsectors such as Specialty REITs, Full Line Insurance, Life Insurance, Multiutilities, Furnishings, and Auto Parts, experience the risk spillover from the crude oil market. It may be due to the impacts of the U.S. recession in the early 1990s and the 1990 oil price shock subsequent of Iraq's invasion of Kuwait which doubled the oil price from July to October, 1990.

Chapter 3

THE NEXUS BETWEEN OIL PRICES AND STOCK PRICES OF OIL, TECHNOLOGY AND TRANSPORTATION COMPANIES

3.1 Introduction

Crude oil is one of the most closely watched commodities in the world and its price is determined by global oil demand and supply conditions. The driving forces behind oil price movements include: increasing global demand for oil by emerging markets, environmental issues like global warming, and energy security issues like potential supply disruptions due to political instability in oil exporting countries. Moreover, concerns of future oil shortages due to the estimates of reaching “peak oil” between 2016 and 2040 affect oil prices as well (Appenzeller 2004). Predicting the future of the oil market is intricate, as the largest oil-consuming nations do not have the largest oil reserves.

North America and Asia Pacific account for approximately 60% of the world's oil consumption while they just comprise 15% of the world's proved oil reserves. On the other hand, five Middle Eastern countries including Saudi Arabia, Iran, Iraq, Kuwait, and United Arab Emirates have almost 50% of the world's proved oil reserves, but their share of the world's oil consumption is less than 10% (BP 2014). Therefore, this oil-rich region has a great export potential and plays a substantial role in the global energy market.

Developed economies heavily rely on the consumption of oil for their economies to thrive, despite the fact that a major proportion of it must be imported from other countries. Therefore, oil price swings, regardless of their causes, can have severe impacts on these economies. Oil price movements affect the production process and financial performance of companies, ultimately influencing their dividend payments, retained earnings, and stock prices (Huang et al. 1996).

Higher oil prices force businesses to slash their consumption and purchase more energy-efficient products in an attempt to shift toward renewable energy sources in the long term. This also encourages technology companies to allocate more funds towards the research and development of new, “green” technologies in order to reduce energy use and costs. Furthermore, higher oil prices are less likely to have similar impacts on different economic sectors as they have dissimilar dependencies on the oil industry. For instance, according to an estimate, higher oil prices will stimulate investment in cutting-edge technologies for more efficient oil extraction methods, leading to higher oil production by drilling companies in the next five years (IEA 2013).

Consequently, the expected boost in oil production can be translated into more cash flow and better financial performance for these companies. However, unlike the oil companies, technology and transportation companies may suffer due to higher oil prices. In the short run, their production costs may rise, but in the medium to long run, they might even experience better financial performance by developing and consuming new energy-efficient products.

A good example of this is the production of the Airbus A350 XWB by EADS in June 2013. This lightweight, carbon composite airliner burns 25% less fuel than the previous generation of comparable aircraft. This is equal to 10.5 million liters of fuel savings per year, which is equivalent to the fuel consumption of roughly 7,500 mid-size cars per year.[2] Although, Airbus spent significant amount of money on the development of this new aircraft, immediately after its first flight in June 2013 the company secured 613 orders worth billions of dollars (the number of orders increased to 780 by the end of February 2015).[3]

This implies that even with higher oil prices, technology companies can achieve better financial performance in the long term. In addition, those transportation firms, which utilize these energy-conserving products, can benefit a lot in terms of fuel cost savings and lower maintenance costs, thus directly affecting their profitability. The purpose of this paper is to empirically investigate the long-run and spillover impacts of crude oil prices on the stock prices of oil, technology and transportation companies listed in U.S. stock markets. The remainder of the study is organized as follows. Section 2 reviews the relevant literature. Section 3 discusses the empirical methodology and data. Empirical analysis and results are presented in Section 4, while Section 5 provides concluding remarks.

3.2 Literature Review

While it is broadly accepted that oil price fluctuations have important effects on the financial performance of a wide variety of companies, there have been relatively few empirical works conducted to examine how sensitive the stock prices of oil, technology and transportation companies are to changes in oil prices. Nandha and

[2] http://www.a350xwb.com/cost-effectiveness
[3] http://www.a350xwb.com/

Faff (2008) studied the impact of oil price changes on 35 Datastream global industry indices over the period of April 1983 to September 2005. They demonstrated that oil price increases have a negative impact on stock returns of all sectors except mining, and oil and gas companies. Henriques and Sadorsky (2008) measured the impact of oil prices on the stock market performance of alternative energy firms. They employed a four-variable vector autoregressive model to examine the nexus between oil prices, interest rates, stock prices alternative energy and technology companies.

Their results confirm the existence of unidirectional Granger causality running from both oil prices and technology stock prices to the alternative energy stock prices. Using impulse response functions, they demonstrate that a shock to stock prices of technology firms has a larger effect on the stock prices of alternative energy companies than does a shock to oil prices. Aggarwal et al. (2012) examined the effect of oil price changes on the S&P transportation companies. They used the daily data of WTI over two decades and found that transportation firms' returns are affected negatively by oil price rises.

Scholtensa and Yurtseverc (2012) study the industry impact of oil price shocks in the EU for the period 1983–2007. They construct dynamic VAR models with various oil price specifications to assess the impact of oil price shocks on 38 different industries. They assert that the influence of oil price shocks considerably varies across the industries under the study. Results indicate that most of the industries are positively affected by negative price shocks while they are not considerably influenced by increasing oil prices.

On the other hand, some industries like oil and gas and mining positively respond to oil price surges and negatively respond to plunging oil prices. Chang et al. (2013) examines the volatility spillovers and conditional correlations between the oil and financial markets. They use daily data of the spot, futures, and forward prices of the WTI and Brent crude oils, and the NYSE, FTSE100, Dow Jones and S&P500 stock index returns from 2 January 1998 to 4 November 2009. They use multiple GARCH family models such as VARMA-GARCH, VARMA-AGARCH, CCC and DCC models. By using the CCC model, they explore the conditional correlations of returns across markets. They find that conditional correlations are very low, and some cases are not statistically significant. They conclude that the shocks are conditionally correlated only in the same market and not between markets. They also find little evidence of volatility spillovers between the crude oil and financial markets using the VARMA-GARCH and VARMA-AGARCH models.

Mohanty et al. (2014) explore the exposure of the U.S. travel and leisure industry to oil price risk. They apply the four-factor asset pricing model of the Fama–French–Carhart (1997) along with the oil price as a risk factor. The results show various degrees of oil price risk exposure across six subsectors. The exposure sign is mostly negative, but it is only significant for some of subsectors including airlines, restaurants and bars, and recreational services. The results also suggest that the exposure of the subsectors to oil price risk vary significantly over time. For instance, the oil price risk exposure of airline industry was the most during the 2007–2008 U.S. subprime mortgage crisis. Wang and Zhang (2014) study the responsiveness of China's major industries to oil price shocks using an ARJI-GARCH method. They concentrated on four major industries: metals, grains, oil fats, petrochemicals.

They also examined the impact of extreme price fluctuations; called jumps. The asymmetric impacts of oil price shocks have been confirmed. According to results, the negative oil price shocks had tougher effects on the four industries. The least sensitive market to oil price shocks was the grains market and the most sensitive market was the petrochemical. In the presence of jumps in the crude oil market, the reactions of four commodity markets would be different. In fact, the petrochemicals and oil fats markets had a tendency to overreact to oil price jumps but there was not such a behavior in the grain and metal markets.

Reboredo and Rivera-Castro (2014) investigate the relationship between oil and stock markets by using wavelet multi-resolution analysis in EU and the US at the aggregate and sectoral levels. They use data for the period June 2000 to July 2011. They employ wavelet decomposition analysis in order to measure interdependence and contagion effects between oil and stock price at various time frames. They find that except for oil and gas companies, oil price fluctuations had no impact on stock market returns in the pre-crisis period at either the sectoral or aggregate level. Contrariwise, they find evidence of positive interdependence and contagion between these markets at the time of financial crisis at the both levels.

3.3 Data and Methodology

3.3.1 Data

This study uses weekly data over the period of January 2, 1990 to February 3, 2015 to assess the short-run and long-run relationships between crude oil prices and the stock prices of oil, technology, and transportation companies. All data were obtained from Thomson Reuters’s Datastream for a total of 1310 weekly observations for each variable. Weekly data is selected as it is less noisy compared to daily data and it relatively captures market movements better than monthly data. The stock market performance of oil companies is measured using the NYSE Arca Oil Index (OIL). This is a price-weighted stock index of the world's top oil companies who deal with the exploration and production of petroleum. The performance of the oil industry is measured by this index through changes in total stock prices of the component.

The index was introduced on August 27, 1984 with a base level of 125.[4] Further, the NYSE Arca Tech 100 Index (TEC) is used to examine the stock market performance of leading technological companies. This is a price-weighted stock index of technology-related firms listed on various US exchanges. The main aim of the index is to benchmark the performance of the firms using technological innovations across different types of industries. The index covers top companies from numerous industries, such as aerospace, biotechnology, electronics, computer software and hardware, semiconductors, telecommunications, and defense.

The index was developed by the Pacific Stock Exchange in 1982 and still operates with the ticker symbol of PSE under NYSE Euronext supervision.[5] Another selected index for this study is the Dow Jones Transportation Average, DJTA (TRA). It is known as the best indicator for the US transportation sector. Its founding date backs to 1884 by Dow Jones & Company, making it the oldest US stock index still in use.

[4] http://www.nyse.com/ listed/lcddata.html? ticker=xoi
[5] http://www.nyse.com/ about/ listed/ pse_i.shtml

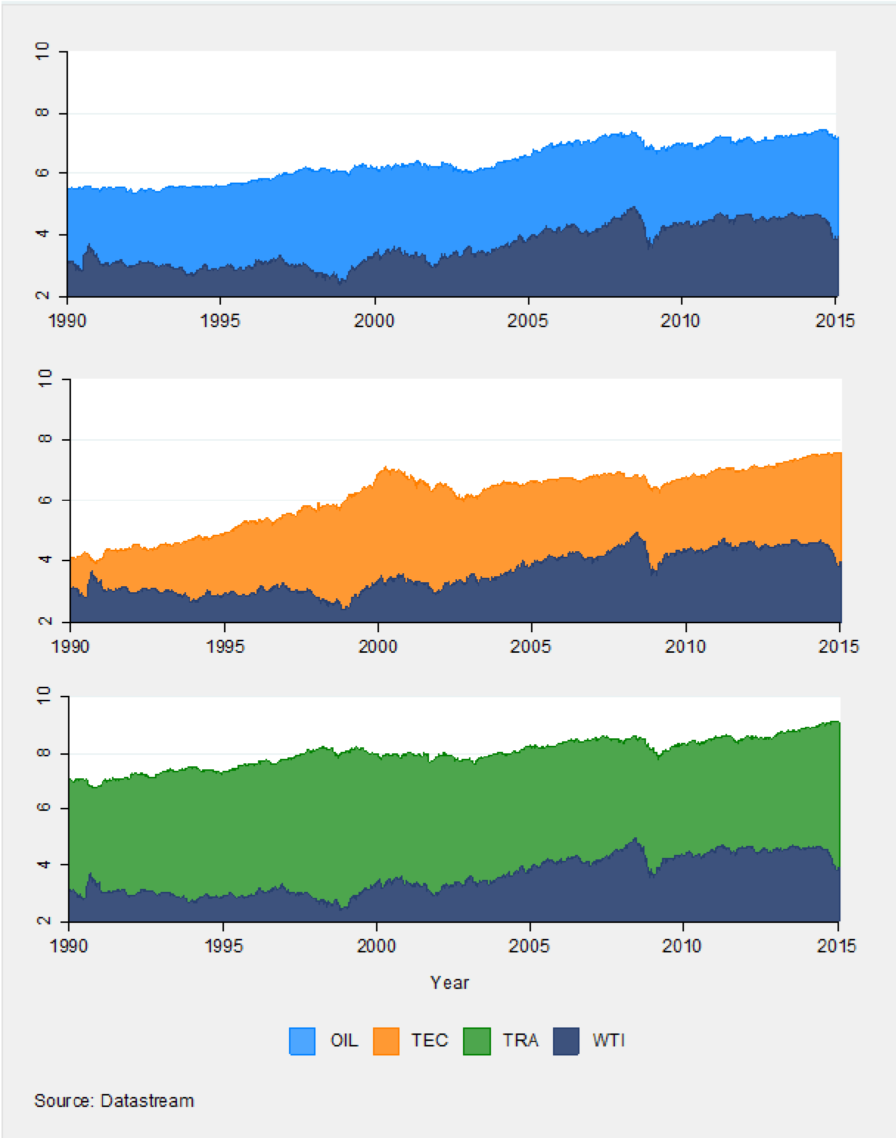


Figure 20. Time series plot of the variables

The index was initially composed of only railroad companies, but now it includes airlines, trucking, marine transportation, and logistics companies as well. The DJTA is also a price-weighted stock index and maintained by Dow Jones Indexes.[6] 3-month U.S. Treasury bill is chosen as the short-term interest rate (SIR) because according to many researchers (Chen et al., 1986; Chen, 1991; Sadorsky, 1999, 2001), it can explain stock price movements. The Standard and Poor's 500 Index (SPX) is also selected to capture market movements at aggregate level.

[6] http://www.djaverages.com/?go=transportation-overview

This study uses West Texas Intermediate crude oil (WTI) spot prices in order to measure the effect of oil prices on stock market performance of oil, technology and transportation companies. Hereafter, the natural logarithm of the data is being used in order to reduce unwanted variability (heteroskedasticity) in the series. Figure 20 illustrates the time series plot of the data. This shows that these stock indices tend to move together and also their movements are very similar to the oil price fluctuations. This means that these variables are highly correlated. The global financial crisis of 2008-2009 had a great impact on the stock prices of oil, technology and transportation companies, and also on crude oil prices.

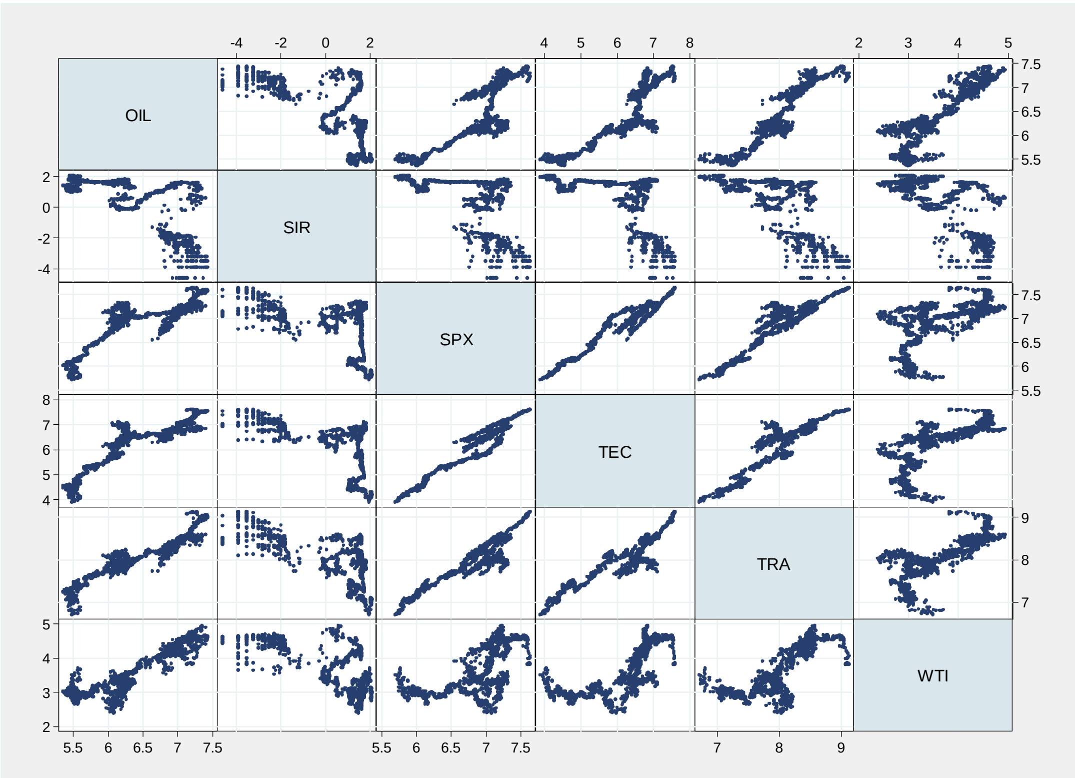


Figure 21. Correlation plot matrix of the variables

As a result, all of the indices experienced a huge plunge ranging from 39% to almost 70% between September 2008 and March 2009. For better understanding of the correlation conditions between these variables, the correlation plot matrix is presented in Figure 21.

3.3.2 Methodology

3.3.2.1 Empirical Model

In this study, we assume the short-term interest rate and the oil prices can explain fluctuations in the aforementioned stock price indices. Thus, the following equations are suggested:

$$OIL_t = \beta_1 + \beta_2 SIR_t + \beta_3 SPX_t + \beta_4 WTI_t + \varepsilon_t \tag{19}$$

$$TEC_t = \alpha_1 + \alpha_2 SIR_t + \alpha_3 SPX_t + \alpha_4 WTI_t + \varepsilon_t \tag{20}$$

$$TRA_t = \gamma_1 + \gamma_2 SIR_t + \gamma_3 SPX_t + \gamma_4 WTI_t + \varepsilon_t \tag{21}$$

where at period t, OIL, TEC and TRA are the natural logarithms of stock indices of oil, technology and transportation companies; SIR is the natural logarithm of short-term interest rate; SPX is the natural logarithm of S&P500 Index; WTI is the natural logarithm of West Texas Intermediate crude oil spot prices; and ε is the error disturbance.

3.3.2.2 Testing for Breaks in the Time Series

Perron and Yabu (2009) introduce a method in an attempt to test the existence of a structural break or regime shift in a univariate time series. The method computes the EXP-W_{RQF} test in order to find a break in a time series that is valid regardless of whether the error term is stationary or not. In other words, the EXP-W_{RQF} test can be employed without knowing whether the series contains an autoregressive unit root or is trend stationary. By using robust quasi-flexible GLS (generalized least squares), this test can detect an unknown break in the intercept, deterministic trend or in both.

3.3.2.3 Unit Root Tests under Multiple Structural Breaks

When the existence of regime shifts is the case, the conventional unit root tests like Phillips and Perron (PP) and Augmented Dickey-Fuller (ADF) cannot be applied due to lack of power. As a result, various unit roots tests in the econometrics literature consider structural breaks. Some of these tests can consider one or two structural breaks (see, for example, Zivot and Andrews, 1992; Lumsdaine and Papell, 1997; Ng and Perron, 2001; Lee and Strazicich, 2003). The newest unit root testing technique available is the one developed by Carrion-i-Silvestre et al. (2009) which allows for up to five breaks in the series. Hence, the unit root test that we apply in this study is superior to other unit root tests employed in the relevant literature, allowing us to be more confident about the unit root test results.

The unit root test of Carrion-i-Silvestre et al. (2009) uses the algorithm of Bai and Perron (2003) in order to identify structural breaks through a quasi-GLS (Generalized Least Squares) method and it minimizes the residual sum of squares through a dynamic programming process. Regarding the stochastic data generation process (DGP) $y_t = d_t + \mu_t$ (where $\mu_t = \alpha\mu_{t-1} + \upsilon_t$ for t = 0, 1, ..., T), Carrion-i-Silvestre et al. (2009) developed the following five different statistics for testing the null hypothesis of a unit root under multiple structural breaks:

$$P_T\left(\lambda^0\right) = \frac{\left[S\left(\overline{\alpha}, \lambda^0\right) - \overline{\alpha} S\left(1, \lambda^0\right)\right]}{S^2\left(\lambda^0\right)} \tag{22}$$

where P_T stands for Gaussian point optimal statistic and S stands for spectral density function.

$$MP_T\left(\lambda^0\right) = \frac{\left[c^{-2} T^{-2} \sum_{t=1}^{T} \tilde{y}_{t-1}^2 + \left(1 - \overline{c}\right) T^{-1} \tilde{y}_T^2\right]}{s\left(\lambda^0\right)^2} \tag{23}$$

where MP_T stands for the modified feasible point optimal statistic according to Ng and Perron (2001).

$$MZ_\alpha\left(\lambda^0\right) = \left(T^{-1}\tilde{y}_T^2 - s\left(\lambda^0\right)^2\right)\left(2T^{-2}\sum_{t=1}^{T}\tilde{y}_{t-1}^2\right)^{-1} \tag{24}$$

$$MSB\left(\lambda^0\right) = \left(s\left(\lambda^0\right)^{-2}T^{-2}\sum_{t=1}^{T}\tilde{y}_{t-1}^2\right)^{1/2} \tag{25}$$

$$MZ_t\left(\lambda^0\right) = \left(T^{-1}\tilde{y}_T^2 \ - s\left(\lambda^0\right)^2\right)\left(4s\left(\lambda^0\right)^2 T^{-2}\sum_{t=1}^{T}\tilde{y}_{t-1}^2\right)^{1/2} \tag{26}$$

where MZ_α, MSB, and MZ_t are M-class test statistics which can obtained using GLS detrending approach (see Carrion-i-Silvestre et al., 2009). The asymptotic critical values are generated through a bootstrapping approach. Rejection of the null hypothesis indicates the stationarity of the series.

3.3.2.4 Maki (2012) Cointegration Test Under Multiple Structural Breaks

According to Westerlund and Edgerton (2006), the conventional cointegration tests for non-stationary series, which do not consider the existence of structural breaks, are likely to provide biased results. To deal with this risk, various methods are available in the relevant literature. For instance, cointegration tests of Carrion-i-Silvestre and Sansó (2006), and Westerlund and Edgerton (2006) allow for one or two breaks in the series. However, when dealing with a long sample period like in this study, the probability of existence of more than two structural breaks is higher and if they are not detected, may compromise the reliability of the results. To address this issue, we employ the newest cointegration test developed by Maki (2012) which allows for consideration of up to five structural breaks. In Maki's (2012) cointegration test, every period can be a possible breaking point and for this reason, a t-statistic for each period is computed. Periods with the lowest t-ratios are recognized as breaking points. Maki (2012) developed four different models that are called “regime shift models” for testing the cointegration, as illustrated below.

Model 1, with a break in the level:

$$y_t = \mu + \sum_{i=1}^{k} \mu_i K_{i,t} + \beta x_t + \upsilon_t \tag{27}$$

Model 2, with a break in the level and coefficients:

$$y_t = \mu + \sum_{i=1}^{k} \mu_i K_{i,t} + \beta x_t + \sum_{i=1}^{k} \beta_i x_i K_{i,t} + \upsilon_t \tag{28}$$

Model 3, with a break in the level and coefficients, and with trend:

$$y_t = \mu + \sum_{i=1}^{k} \mu_i K_{i,t} + \gamma x + \beta x_t + \sum_{i=1}^{k} \beta_i x_i K_{i,t} + \upsilon_t \tag{29}$$

Model 4, with a break in the level, coefficients, and trend:

$$y_t = \mu + \sum_{i=1}^{k} \mu_i K_{i,t} + \gamma t + \sum_{i=1}^{k} \gamma_i t K_{i,t} + \beta x_t + \sum_{i=1}^{k} \beta_i x_i K_{i,t} + \upsilon_t \tag{30}$$

where K_i stands for dummy variables that are defined by Maki (2012) as:

$$K_i = \begin{cases} 1 & when\ \mathrm{t} > \mathrm{T_B} \\ 0 & otherwise \end{cases}$$

where T_B stands for break point. The Monte Carlo simulations are used for computation of critical values to test the null hypothesis of ‘no cointegration’ under multiple structural breaks (see Maki, 2012).

3.3.2.5 Estimation of Long-Run Coefficients using DOLS

Once a cointegrating vector is determined, then the dynamic OLS (DOLS) approach can be used to estimate the long-run coefficients of equations (19-21). As suggested by Stock and Watson (1993), by addition of lagged structures and differenced of independent variables to their level forms, consistent estimators can be obtained by eradicating any autocorrelation, endogeneity and simultaneity problems. Therefore, DOLS models can be employed regardless of the order of integration of the variables. The DOLS models will be used to estimate equations (19-21)**,** which can be expressed as follows:

$$OIL_t = B'X + \sum_{i=-q}^{q} \mu_i \Delta SIR_{t-i} + \sum_{i=-q}^{q} \eta_i \Delta SPX_{t-i} + \sum_{i=-q}^{q} \lambda_i \Delta WTI_{t-i} + \varpi D_i + \varepsilon_t \tag{31}$$

$$TEC_t = B'X + \sum_{i=-q}^{q} \mu_i \Delta SIR_{t-i} + \sum_{i=-q}^{q} \eta_i \Delta SPX_{t-i} + \sum_{i=-q}^{q} \lambda_i \Delta WTI_{t-i} + \varpi D_i + \varepsilon_t \tag{32}$$

$$TRA_t = B'X + \sum_{i=-q}^{q} \mu_i \Delta SIR_{t-i} + \sum_{i=-q}^{q} \eta_i \Delta SPX_{t-i} + \sum_{i=-q}^{q} \lambda_i \Delta WTI_{t-i} + \varpi D_i + \varepsilon_t \tag{33}$$

where B = [c, α, β, γ], X = [1, SIR_t, SPX_t, WTI_t], and q stands for the lag structure to be determined by the Akaike Information Criterion (AIC), and t is a time trend. D_i stands for dummy variables of week breaks which are allowed up to a maximum of five, and they are selected based on the Model 4 of Maki's (2012) cointegration test.

3.3.2.6 Breakpoint Regression

Given the occurrence of some structural changes in oil and financial markets over the last three decades, it is necessary to test the existence of structural breaks in the relationship between the stock prices of oil, technology, transportation companies, and crude oil price. This can be done using the method introduced by Bai and Perron (2003). This approach allows testing for multiple structural breaks in a linear model. Then, via using least squares estimation, it can detect breaks at a priori unknown dates. Allowing for multiple breaks in the explanatory factors, the Eq. (19-21) can be reformulated and use the following regression model with *m* breaks (*m* + 1 regimes[7]):

[7] A “regime” means a period. If there is one break, there will be two regimes.

$$OIL_t = \alpha_j + \beta_j SIR_t + \gamma_j SPX_t + \delta_j WTI_t + \varepsilon_t \quad (34)$$

$$TEC_t = \alpha_j + \beta_j SIR_t + \gamma_j SPX_t + \delta_j WTI_t + \varepsilon_t \quad (35)$$

$$TRA_t = \alpha_j + \beta_j SIR_t + \gamma_j SPX_t + \delta_j WTI_t + \varepsilon_t \quad (36)$$

where $t = T_{j-1} + 1, \ldots, T_j$ and $j = 1, \ldots, m + 1$. The breakpoints ($T_1, \ldots, T_m$) are explicitly treated as unknown, and by convention, $T_0 = 0$ and $T_{m+1} = T$ where T is the total sample size. The Bai-Perron sequential test statistics detects the number of breaks. The SupF (l +1 | l) test is a sequential test of the null hypothesis of l breaks versus the alternative of $l + 1$ breaks. Later, the breakpoint regression is used to estimate the Eqs. (34-36) for the sub-periods based on breakpoint(s) determined by the Bai-Perron sequential test results.

3.3.2.6 Time-varying Causality

In order to test the spillover between oil prices and the stock indices of the oil, technology, and transportation industries, the causal linkages between them should be examined. This method is explained in detail in section 2.3.2.3.

3.4 Empirical Analysis and Results

The Perron and Yabu (2009) Exp-W_{RQF} test statistics and the corresponding breaking weeks are reported in Table 26. The Exp-W_{RQF} test statistic is estimated based on the Model 3 of Perron and Yabu (2009) which permits structural break in both level and trend. According to the results that are shown in Table 26, we can strongly reject the null hypothesis of not having structural break in both level and trend. Alternatively, it is indicating that there is at least one regime shift in each series under consideration.

Table 26. Perron and Yabu (2009) break test results

	OIL	SIR	SPX	TEC	TRA	WTI
EXP-W_{RQF}	31.2509[a]	46.8299[a]	24.6342[a]	23.5144[a]	15.3095[a]	14.2044[a]
TB	2005W38	2008W43	2008W21	2001W30	1999W42	2004W16

Note: a denotes statistical significance at 1% level. The asymptotic critical values for the EXP-W_{RQF} are 2.48, 3.12, and 4.47 (for a break in the constant and time trend slope) at 10%, 5%, and 1% significance level, respectively (Perron & Yabu, 2009).

Table 27 provides the Carrion-i-Silvestre et al. (2009) unit root tests results for the variables under consideration. The results suggest five structural breaks in each series. Given these breaks, all the series seem to be non-stationary in levels because the null hypothesis of having a unit root cannot be rejected. On the other hand, all the series become stationary in their first differences. Evidently, it is concluded that the series of the present study are integrated of order one, I(1). Since all the series are integrated of the same order, I(1), the existence of any cointegrating relationship can be examined by using cointegration tests. As it is mentioned before, this study employs Maki's (2012) approach to test for cointegration.

Table 27. Carrion-i-Silvestre et al. (2009) unit root test results

	Levels					Breaking Weeks
	P_T	MP_T	MZ_α	MSB	MZ_t	
OIL	11.55	11.4	-39.17	0.11	-4.41	1996W22; 1998W18; 2001W36; 2003W32; 2005W45
	[9.56]	[9.56]	[-46.49]	[0.10]	[-4.75]	
SIR	24.72	20.95	-16.86	0.17	-2.9	1999W41; 2001W36; 2005W49; 2008W52; 2011W15
	[7.92]	[7.92]	[-44.01]	[0.10]	[4.70]	
SPX	19.15	17.37	-25.94	0.14	-3.57	1994W50; 1999W41; 2002W41; 2005W42; 2008W21
	[9.33]	[9.33]	[-47.10]	[0.10]	[4.83]	
TEC	12.76	11.38	-39.7	0.11	-4.45	1998W40; 2000W35; 2002W39; 2004W30; 2009W09
	[9.51]	[9.51]	[-46.97]	[0.10]	[-4.80]	
TRA	13.29	11.1	-39.92	0.11	-4.46	1997W27; 1999W18; 2003W10; 2006W18; 2009W09
	[9.21]	[9.21]	[-47.48]	[0.10]	[-4.86]	
WTI	18.74	17.06	-26.27	0.13	-3.62	1997W02; 1999W01; 2000W02; 2003W39; 2008W29
	[9.36]	[9.36]	[-47.11]	[0.10]	[-4.82]	
	First Differences					
DOIL	0.19[a]	0.19[a]	-471.27[a]	0.03[a]	-15.34[a]	-
	[5.54]	[5.54]	[-17.32]	[0.16]	[-2.89]	
DSIR	0.19[a]	0.19[a]	-472.34[a]	0.03[a]	-15.36[a]	-
	[5.54]	[5.54]	[-17.32]	[0.16]	[-2.89]	
DSPX	0.19[a]	0.19[a]	-473.64[a]	0.03[a]	-15.39[a]	-
	[5.54]	[5.54]	[-17.32]	[0.16]	[-2.89]	
DTEC	0.19[a]	0.19[a]	-469.23[a]	0.03[a]	-15.31[a]	-
	[5.54]	[5.54]	[-17.32]	[0.16]	[-2.89]	
DTRA	0.19[a]	0.19[a]	-470.79[a]	0.03[a]	-15.34[a]	-
	[5.54]	[5.54]	[-17.32]	[0.16]	[-2.89]	
DWTI	0.19[a]	0.19[a]	-465.13[a]	0.03[a]	-15.24[a]	-
	[5.54]	[5.54]	[-17.32]	[0.16]	[-2.89]	

Note: a denotes the rejection of the null hypothesis of a unit root at the 5% level. Numbers in brackets are critical values derived from the bootstrap approach after 1000 simulations. Breaking weeks are automatically estimated and determined by Carrion-i-Silvestre et al. (2009) unit root tests in GAUSS software.

Table 28. Maki (2012) cointegration tests

Cointegration model: OIL = f (SIR, SPX, WTI)				
Model options	Statistics	CV 1%	CV 5%	Break weeks
Model 1	-7.53[a]	-6.55	-6.03	1991W47; 1994W28; 1996W04; 2004W21; 2008W36
Model 2	-7.76[a]	-6.78	-6.25	1996W04; 1999W21; 2001W14; 2004W21; 2007W01
Model 3	-9.21[a]	-8.67	-8.11	1994W34; 1996W11; 1999W21; 2004W21; 2008W37
Model 4	-9.97[a]	-9.43	-8.81	1991W47; 1996W40; 2000W36; 2003W48; 2007W12
Cointegration model: TEC = f (SIR, SPX, WTI)				
Model options	Statistics	CV 1%	CV 5%	Break weeks
Model 1	-37.07[a]	-6.55	-6.03	1996W46; 1999W24; 2000W20; 2004W31; 2008W12
Model 2	-37.82[a]	-6.78	-6.25	1998W01; 2000W25; 2001W11; 2006W39; 2008W11
Model 3	-37.51[a]	-8.67	-8.11	2001W21; 2006W38; 2008W12; 2010W46; 2012W06
Model 4	-38.30[a]	-9.43	-8.81	2002W19; 2004W32; 2008W21; 2012W05; 2013W23
Cointegration model: TRA = f (SIR, SPX, WTI)				
Model options	Statistics	CV 1%	CV 5%	Break weeks
Model 1	-5.43	-6.55	-6.03	1996W37; 2000W21; 2001W27; 2005W10; 2008W09
Model 2	-6.80[a]	-6.78	-6.25	1991W17; 1995W13; 2000W21; 2004W41; 2007W11
Model 3	-7.43	-8.67	-8.11	1994W32; 2001W28; 2005W11; 2008W19; 2012W21
Model 4	-9.30[b]	-9.43	-8.81	1996W37; 1998W43; 2001W26; 2005W08; 2009W19

Notes: a and b denote the rejection of the null hypothesis of no cointegration at the 1%, and 5% levels, respectively. Critical values (CV) were gathered from Table 1of Maki (2012): which allows breaks in trend and intercept through two independent variables.

Table 28 present the Maki's (2012) cointegration tests results. As can be seen from the results, in the presence of multiple structural breaks or regime shifts, the null hypothesis of 'no cointegration' can be rejected by all of the four models suggested by Maki (2012). The results reveal that equations (19-21) cointegrate and thus, there are long-run equilibrium relationships between these variables. Furthermore, according to the Granger representation theorem, an equilibrium correction model can be constructed for any cointegrating relationship (Brooks, 2014). It should be noted that the breaking weeks that have been identified by the model 4 of Maki (2012) are added to the estimation of the long-run coefficients via dummy variables (D1-D5).

Table 29 exhibits the level coefficients of the long-run models as shown in Eq. (31-33) that are estimated via the DOLS method. The results suggest that short-term interest rate (SIR) exerts a negative significant impact on the stock price indices of oil, technology, and transportation companies. The S&P 500 (SPX) has a positive and significant effect on the stock price indices. But, as expected, the impact magnitude of SPX is much higher than that of SIR and WTI on the stock price indices which indicates the importance of the broad market index in determining stock prices.

Table 29. Estimation of level coefficients in the long-run models using DOLS

	SIR	SPX	WTI	D1	D2	D3	D4	D5	C	R^2	DW
OIL	-0.005[c]	0.601[a]	0.569[a]	-0.053	-0.051	-0.325[a]	-0.270[b]	0.163	0.221[a]	0.963	1.87
	(0.003)	(0.092)	(0.085)	(0.124)	(0.124)	(0.125)	(0.124)	(0.124)	(0.056)		
TEC	-0.056[c]	1.664[b]	0.204[b]	0.496[c]	0.222	-0.884[b]	-0.041	-0.683[c]	-0.598	0.778	1.92
	(0.033)	(0.710)	(0.101)	(0.298)	(0.297)	(0.390)	(0.304)	(0.399)	(0.659)		
TRA	-0.034[c]	0.762[b]	0.210[b]	0.304	1.498[b]	-1.194[b]	-0.231	-0.096	2.027	0.901	2.04
	(0.019)	(0.350)	(0.101)	(0.642)	(0.686)	(0.659)	(0.645)	(0.701)	(1.961)		

Note: a, b, and c denote significance at 1%, 5%, and 10% levels respectively. Standard errors of the estimated coefficients are corrected for heteroscedasticity by the White procedure. Dummy variables have been assigned for breaking weeks (D1-D5) and these breaks are selected based on the Model 4 of Maki's (2012) cointegration test. DW shows the Durbin-Watson test statistics.

On the other hand, West Texas Intermediate crude oil (WTI) has a positive and statistically significant impact on all of the stock price indices. The positive oil coefficient of technology stocks suggests that even high oil prices can improve the financial performance and profitability of technology companies as they move toward innovating more new energy-efficient and sustainable products. For instance, in June 2012 Tesla Motors unveiled an all-electric sedan (Model S), which is one of the most advanced electric vehicles. Due to its rapidly growing sales, the company's stock price skyrocketed from almost $30 in June 2012 to $282 in July 2015, which is equivalent to a 940% return in two years! This shows that the market is moving toward a future less reliant on fossil fuels. Moreover, it should be noted that the extent of impact of WTI on oil companies is much higher than that of WTI on technology and transportation companies. This suggests that the oil-sensitive stocks have a tendency to be affected relatively more by crude oil price fluctuations. This result is in accordance with findings of Click (2001), Sadorsky (2001), Hammoudeh and Li (2004), Nandha and Faff (2008), Gogineni (2010), Mohanty et al. (2014), Demirer et al. (2015), and Shaeri et al. (2016). The majorities of dummy variables are also significant and have mixed signs.

Table 30. Structural breaks in the relationship between stock indices and the explanatory variables

Company	$SupF_t$					Number of breaks			Break dates
	(1 | 0)	(2 | 1)	(3 | 2)	(4 | 3)	(5 | 4)	Seq.	BIC	LWZ	
OIL	472.09[a]	159.38[a]	83.72[a]	84.76[a]	0.00	4	3	2	1997W22; 2001W20;
	(16.19)	(18.11)	(18.93)	(19.64)	(20.19)				2005W07; 2008W47
TEC	514.18[a]	413.60[a]	149.33[a]	336.12[a]	0.00	4	1	1	1996W02; 1999W49;
	(16.19)	(18.11)	(18.93)	(19.64)	(20.19)				2006W19; 2010W09
TRA	543.03[a]	231.82[a]	172.52[a]	67.88[a]	0.00	4	2	1	1994W31; 1999W32;
	(16.19)	(18.11)	(18.93)	(19.64)	(20.19)				2002W19; 2008W14

Note: This table shows the test results for the endogenous structural breaks as developed by Bai and Perron (2003). Five breaks are allowed at most and the trimming parameter is 0.15. The $SupF_t$ (l +1 | l) is a sequential test of the null of l breaks versus the alternative of l +1 breaks. Sequential, BIC and LWZ denote the procedure of sequentially determined breaks, Bayesian Information Criterion and Information Criterion proposed by Liu, Wu and Zidek (1997), respectively. a denotes statistical significance at 5% level.

Table 30 reports the results of Bai and Perron (2003) test for identifying the multiple structural breaks in the relationship between the stock indices and the explanatory variables. The results of the sequential test show that the oil, technology, and transportation companies have four structural breaks at 5% significance level. This implies that assuming the oil price sensitivity is constant over time is not true. Thus, it confirms the shortcomings of prior studies based on this assumption. In this Table, columns seven, eight and nine show the number of breaks identified by the sequential approach of the Bai and Perron (2003) test and the BIC and LWZ information criteria, accordingly. Once the structural breaks in the relationship between the stock indices and the explanatory variables are identified, Eqs. (34-36) are estimated for the sub-periods based on the breakpoints identified by the Bai-Perron sequential test.

Table 31. Breakpoint regression results

Company	Breaks	Obs	Sub-samples	SIR	SPX	WTI	C	R^2	DW
OIL	4	387	1990W01 - 1997W21	0.142^{a}	0.623^{a}	0.157	1.082^{b}	0.812	1.95
				(0.053)	(0.058)	(0.095)	(0.467)		
		206	1997W22 - 2001W19	-0.360^{c}	0.053	0.253^{a}	1.616^{a}		
				(0.207)	(0.155)	(0.085)	(1.008)		
		196	2001W20 - 2005W06	0.091	0.832^{a}	0.380^{a}	-0.845		
				(0.058)	(0.203)	(0.083)	(1.349)		
		196	2005W07 - 2008W46	-0.140^{b}	1.384^{a}	0.213^{c}	-1.630		
				(0.060)	(0.333)	(0.112)	(2.034)		
		325	2008W47 - 2015W05	-0.017	0.545^{a}	0.140^{c}	2.511^{a}		
				(0.023)	(0.082)	(0.072)	(0.509)		
TEC	4	314	1990W01 - 1996W02	0.226^{a}	2.192^{a}	-0.109^{a}	-1.697^{a}	0.921	1.96
				(0.010)	(0.029)	(0.025)	(0.323)		
		204	1996W02 - 1999W48	-0.350	1.518^{a}	0.482^{c}	-1.473		
				(0.756)	(0.369)	(0.281)	(0.911)		
		335	1999W48 - 2006W18	-0.056^{c}	1.800^{a}	0.068	-1.309		
				(0.030)	(0.059)	(0.106)	(0.724)		
		199	2006W19 - 2010W08	-0.040	0.874^{a}	0.075^{b}	0.185		
				(0.046)	(0.215)	(0.033)	(1.607)		
		258	2008W09 - 2015W05	-0.011^{a}	1.216^{a}	0.034^{a}	-1.874^{a}		
				(0.002)	(0.007)	(0.008)	(0.073)		
TRA	4	239	1990W01 - 1994W30	0.106^{a}	1.617^{a}	-0.193^{a}	-1.082^{a}	0.597	1.96
				(0.016)	(0.054)	(0.023)	(0.389)		
		262	1994W31 - 1999W31	0.535^{a}	0.936^{a}	0.065	0.506		
				(0.092)	(0.192)	(0.279)	(2.105)		
		143	1994W32 - 2002W18	-0.050	0.223	0.128	1.982		
				(0.242)	(0.418)	(0.571)	(1.661)		
		308	2002W19 - 2008W13	0.066	1.050^{a}	0.187	-0.037		
				(0.214)	(0.298)	(0.504)	(0.390)		
		358	2008W14 - 2015W05	-0.001	1.182^{a}	-0.057^{a}	0.293^{a}		
				(0.002)	(0.009)	(0.008)	(0.067)		

Note: This table reports the breakpoint regression results of linear models in Eqs. (16-18). Sub-samples are based on the breakpoints identified by the test of Bai and Perron (2003). Five breaks are allowed at most. Standard errors of the estimated coefficients are corrected for heteroscedasticity by the White procedure. Breaks denote the number of breaks selected by the sequential procedure of Bai and Perron (2003) at 5% statistical significance level. DW shows the Durbin-Watson test statistics. Obs shows the number of observations in each sub-sample. a, b, and c denote statistical significance at the 1%, 5% and 10% levels, respectively.

This method instead of putting break dates as the dummy variables into the regression model, it segments the regression into multiple regimes based on the identified break dates. Results of the breakpoint regressions are presented in Table 31. The results help us to see how regression coefficients are evolving throughout the time. Due to the existence of four breaks in each regression, there are five different regimes and each regime has its own coefficients. For instance, the negative effect of SIR changes over time and in some periods becomes positive. The results also show that the SPX is a key factor in determining the stock prices of these companies and its coefficients are statistically significant and positive for all companies. Overall, TEC companies receive the highest impact from SPX compared to OIL and TRA companies. Regarding the impact of crude oil on stock prices of the companies, it is clear that oil companies (OIL) relatively receive the highest impact from WTI price movements. However, the impact magnitudes of WTI on the companies' stocks are changing over time and regimes. The results are almost consistent with the results of DOLS.

In order to test the spillover effect between oil prices and the stock indices of the companies, the causal linkages between them should be examined. This study employs the Hill's (2007) fixed-length rolling window causality test. He suggests a successive multi-horizon non-causality test, which can be adopted to detect non-linear causalities in terms of linear parametric restrictions for a trivariate process (two different time series plus an auxiliary variable). This study utilizes the bivariate case where causality between two different time series is measured. Causality takes place at any horizon if and only if it takes place at horizon 1 (first week in each window).

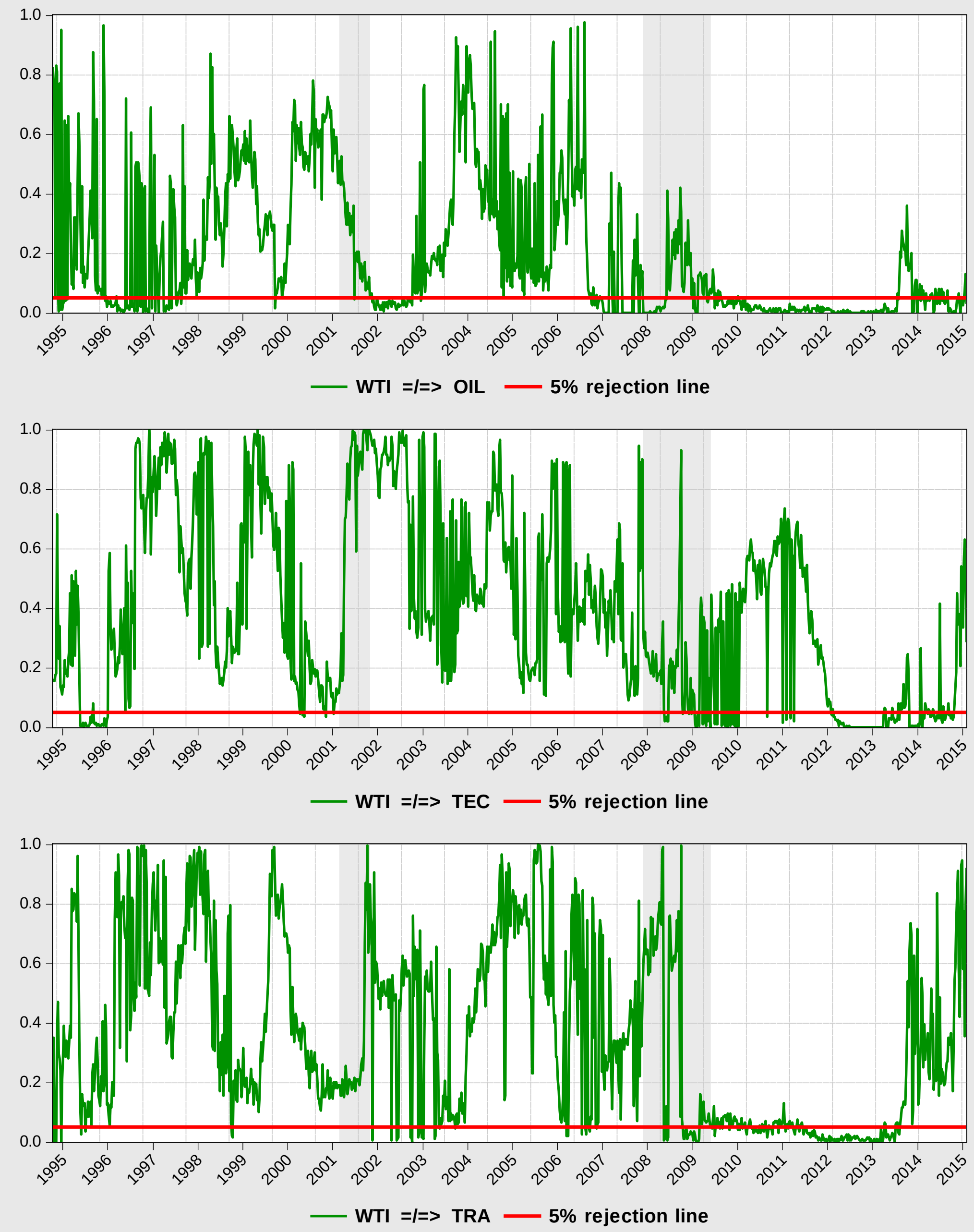
Due to likely substandard performance of the chi-squared distribution in small samples, Hill (2007) proposed a parametric bootstrapping approach for estimating small sample p-values. Also, the length rolling window is fixed at 250 weeks and the maximum order of the VAR model is 4 lags.

Table 32. Time-varying causality using bootstrap rolling-window approach

Null hypothesis (H_0)	Avg. VAR order	Avg. BPV	Rejection rate of H_0
WTI $\nrightarrow$ OIL	1.5655	0.2026	51.6494
WTI $\nrightarrow$ TEC	1.9877	0.3981	22.8087
WTI $\nrightarrow$ TRA	1.5749	0.3550	30.2544
OIL $\nrightarrow$ WTI	1.5655	0.4311	9.6136
TEC $\nrightarrow$ WTI	1.9877	0.3444	21.6776
TRA $\nrightarrow$ WTI	1.5749	0.4068	16.5881

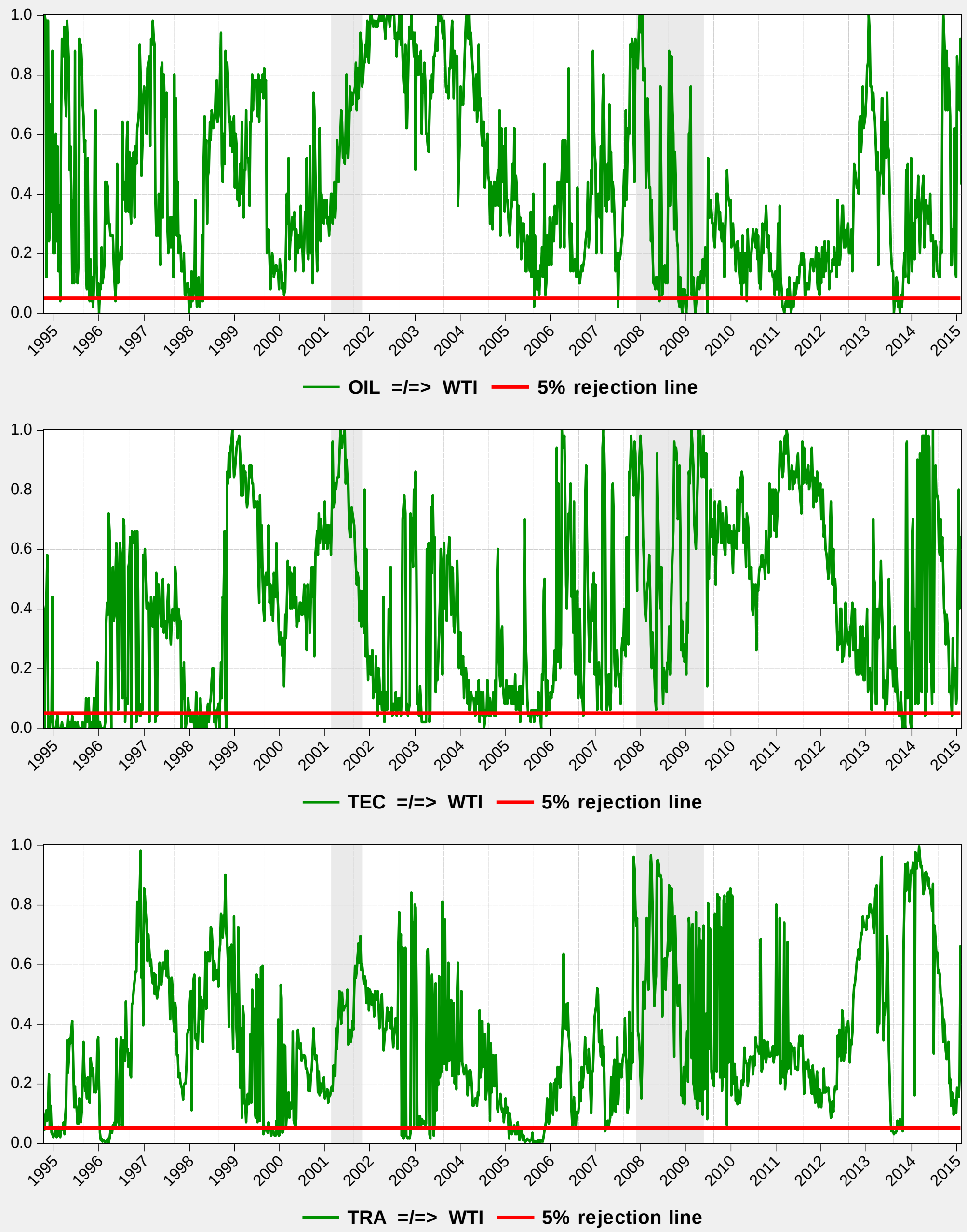
Notes: This table reports the results of Hill's (2007) time-varying causality test. $\nrightarrow$ denotes the non-causality null hypothesis. VAR denotes Vector Autoregressive model and BPV denotes the bootstrap P-values. The maximum order of VAR model is 4 lags. Size of the fixed rolling-window is 250 weeks. Bootstrap iterations are 1000 times. BPVs of less than 5% indicate causality within that window.

Table 32 presents the time-varying causality between oil prices and the stock prices of the oil, technology, and transportation companies. The results show that the null hypotheses of non-causality running from WTI to the sock indices of oil, technology, and transportation companies are rejected at 51.6%, 22.8%, and 30.2% of the time, respectively. In other words, the strongest causality exists from WTI to oil companies which is quite logical as the crude oil is the main product of these companies. Furthermore, the second-strongest causal linkage exits between WTI and transportation companies since fuel is the key input for this industry. The results also show that the null hypotheses of non-causality running from the sock indices of oil, technology, and transportation companies to WTI are rejected at 9.6%, 21.7%, and 16.6% of the time, respectively. Unlike the previous causality results, OIL has a little causal impact on WTI as the causality degree has dropped from 51.6% to 9.6%.



Note I: =/=> denotes "non-causality" running from WTI to the stock indices.
Note II: Shaded areas indicate the recessionary periods in the U.S.
Note III: Y-axis shows the bootstrap p-values based on 1000 iterations.
Source: Authors' calculation

Figure 22. Time-varying causality (from WTI to the stock indices)



Note I: =/=> denotes "non-causality" running from the stock indices to WTI.
Note II: Shaded areas indicate the recessionary periods in the U.S.
Note III: Y-axis shows the bootstrap p-values based on 1000 iterations.
Source: Authors' calculation

Figure 23. Time-varying causality (from the stock indices to WTI)

Therefore, we can say that WTI is relatively more likely to affect the stock prices rather than to be affected by them. The results suggest that technology companies relatively have more ability to influence crude oil prices, most probably through the channel of technological changes and innovations. Figure 22 and 23 illustrate the time-varying causality between WTI and the stock indices. By means of this method we can easily understand the causal dynamics between these variables in a time-varying manner. As can be seen from the Figure 22, after the global financial crisis of 2008-2009, there are high levels of causality running from WTI to all of the stock indices of companies. But except from crisis period, there are not strong causal relationship running from WTI to the companies. Thus, we can say that return spillovers from WTI to these companies mainly occur during financial crises. On the other hand, Figure 23 exhibits the time-varying causality running from stock indices of the companies to WTI. This Figure shows that the degree of causality is from OIL, TEC, and TRA to WTI is relatively low. This demonstrates that the stock prices of these companies are not relatively powerful enough to affect crude oil prices. This also implies that the causal linkage between WTI and these stock indices is more unidirectional rather than to be bidirectional.

3.5 Conclusion

The present study has investigated the impact of crude oil prices on the stock prices of oil, technology, and transportation companies listed on U.S. stock exchanges, using weekly data covering the period from January 2, 1990 to February 3, 2015. The Maki (2012) cointegration tests results reveal that long-run equilibrium relationships exist between these stock indices, crude oil prices, short-term interest rate, and S&P 500 in the presence of multiple structural breaks.

These findings indicate that crude oil prices, short-term interest rates, and the S&P 500 are long-run determinants of the stock prices of oil, technology, and transportation firms. The DOLS results show that stocks prices of oil companies are positively and significantly affected by crude oil prices to a greater degree than that of technology and transportation stocks. This implies that the oil-sensitive stocks have a tendency to be affected relatively more by crude oil price fluctuations.

Results also point out that technology stocks are positively and significantly affected by crude oil prices which indicates that increasing crude oil prices put more pressure on technology firms to lower their energy-related costs and innovate more energy-conserving products due to high demand from other sectors. Therefore, if technology companies are successful in meeting these demands, their financial performances will also improve. Consequently, as these demanding industries utilize these innovative products, they can benefit a lot in terms of fuel cost savings and lower maintenance costs, thus directly affecting their profitability.

The results of the breakpoint regressions are almost in line with the DOLS results, but they give us a hint about how the oil price exposure of these companies changing over time as it takes multiple regimes into account and provides regime-dependent coefficients. Time-varying causality results show that WTI is relatively more likely to affect the stock prices of oil, technology, and transportation companies rather than to be affected by them. Evidently, it is confirmed that financial crises have a substantial ability to intensify the causal linkage between WTI and the stock indices of these companies.

These findings contribute to the relevant literature suggesting that although oil price swings may not be the main reasons behind the stock price movements of technology and transportation companies, but they have enough power to stimulate a movement toward a business environment that would be less reliant on fossil fuels. This is because investors may perceive technological advancements and innovations as the most important factors that influence the profitability of these companies and therefore affect their stock prices.

The implications of this study are important and beneficial for financial managers, CFOs, hedge funds, and portfolio managers. They have to pay special attention to the oil prices exposure of their companies or portfolios as the degree of causality and cross-market spillover tend to be intensified between these markets in the course of financial crises. Finally, it should be noted that in the future, crude oil will probably lose more of its influence on the stock prices of these firms due to the dominance of renewable energies and the proliferation of energy-efficient and sustainable products.

Chapter 4

CONCLUSION AND POLICY IMPLICATIONS

4.1 Concluding Remarks

4.1.1 First Study

This study examines the oil price risk exposure of the financial and non-financial subsectors in the U.S. stock markets over the period from January 1983 to March 2015. In these analyses, the existence of structural breaks in the equity returns of the industry subsectors is taken into account. The Bai and Perron (2003) approach is used to identify multiple breakpoints. By employing the Fama and French (2015) five-factor asset pricing model integrated with oil price risk factor, the oil price risk exposures of the financial and non-financial industries are estimated. Additionally, via the Hill's (2007) time-varying causality in return, the subsectors which receive the highest level of return spillover from crude oil have been identified. Lastly, by means of the GED-EGARCH-VaR approach, the risk spillover from WTI to the financial and non-financial subsectors have examined in a time-varying manner. The most important outcomes of this study can be listed as follows:

1. The majority of financial and non-financial subsectors are affected by oil price changes, but the magnitude of the impact appears to be rather limited.
2. The size of oil price sensitivity differs noticeably across subsectors and over time.
3. Some industries have experienced substantial changes in their oil price exposures in the pre- and post-break periods.

4. The majority of financial subsectors are affected negatively, and most of the non-financial subsectors are affected positively, by oil prices.
5. The magnitude of the impact of oil prices on the financial subsectors is much lower than the magnitude of their impact on the non-financial subsectors.
6. Among the financial subsectors, Mortgage Finance and Real Estate Services have the largest negative and positive exposures to the oil price risk, respectively.
7. Among the non-financial subsectors, Airlines and Oil Equipment Services have the largest negative and positive oil price risk exposures, respectively.
8. MKT, SMB and HML which are the risk factors in the FF3F model have relatively higher role in explaining the returns for the financial subsectors than those for the non-financial subsectors.
9. The recently introduced Fama-French risk factors, RMW and CMA, along with OIL, play more important role for defining the equity returns for the non-financial subsectors than those for the financial subsectors.
10. For the both types of subsectors, market portfolio, MKT, has the highest share among other risk factors in determining the subsectors' returns.
11. HML is the second most important risk factor for the financials, which suggests the important role of book-to-market ratio in asset valuation of financial stocks.
12. CMA is the second most important risk factor for the non-financials, which points out the importance of conservative and aggressive investment strategies in pricing non-financial stocks.
13. OIL has the least important role in explaining the subsectors' returns for the both financials and non-financials.

14. Full Line Insurance, Life Insurance, Banks, Hotel & Lodging REITs, and Residential REITs are the top financials subsectors, receiving the highest time-varying causality in return from crude oil market.
15. Auto Parts, Electronic Office Equipment, Tires, Furnishings, and Commodity Chemicals are the top non-financials subsectors which receive the highest level of return spillover from crude oil during the period of the study.
16. There are high levels of return spillover from oil market to financial and non-financial subsectors in the post 1990-91 and 2008-09 recessions.
17. It is verified that the tails of financials, non-financials and WTI returns are heavier than the tails of standard normal distribution.
18. The volatility persistence is relatively high for almost all of the subsectors and WTI. Hence, volatility shocks decay calmly.
19. Volatility shocks are relatively more persistent in the financials rather than non-financials.
20. In testing the leverage effect, it is revealed that for the both financial and non-financial subsectors, bad news generates more volatility than good news.
21. The VaR estimates of non-financials are more precise than those of the financials. Thus, modeling the risk for the financials is more difficult than that of the non-financials.
22. The top-five riskiest financial subsectors based on the estimated VaRs, are Real Estate Services, Investment Companies, Investment Services, Mortgage Finance, and Hotel & Lodging REITs.
23. The top-five riskiest non-financial subsectors based on the estimated VaRs, are Platinum & Precious Metals, Renewable Energy Equipment, Consumer Electronics, Tires, and Travel & Tourism.

24. Based on the VaRs, the least risky financial subsector is Property & Casualty Insurance and the least risky non-financial subsector is Food Products.
25. The VaRs are unable to effectively define the maximum amount of risk during the U.S. recessions especially throughout the 2008-2009 crisis.
26. Consumer Finance and Insurance Brokers are the financial subsectors which receive the lowest and highest levels of risk spillover from crude oil, respectively.
27. Broadcasting & Entertainment and Multiutilities are the non-financial subsectors which receive the lowest and highest levels of risk spillover from crude oil, respectively.
28. Among the financials, Insurance Brokers, Specialty REITs, Full Line Insurance, Life Insurance, and Banks are the subsectors receiving the highest causality in risk from the oil market.
29. Among the non-financials, Multiutilities, Furnishings, Travel & Tourism, Broadline Retailers, and Auto Parts are the subsectors which receive the highest level of risk spillover effect from the crude oil market.
30. Risk spillovers from the oil market toward financial and non-financial subsectors intensify during and after the 2008-09 financial crisis.
31. Among the financials, the most continuous risk spillover effect occurs for Insurance Brokers starting from mid-2007 to mid-2013.
32. For the non-financials, the most continuous risk spillover effect happens for Travel & Tourism starting from mid-2008 to mid-2014.
33. Overall, it can be concluded that the risk from the crude oil market tends to be transferred to these markets mainly in the course of financial crises.

4.1.2 Second Study

This study investigates the impact of crude oil prices on the stock prices of oil, technology, and transportation companies listed on U.S. stock exchanges, using weekly data covering the period from January 2, 1990 to February 3, 2015. Considering the importance of regime shifts or structural breaks in econometric analysis, this study employs the Carrion-i-Silvestre et al. (2009) unit root tests and the Maki (2012) cointegration tests allowing for multiple breaks. DOLS results show that stock prices of oil companies are positively and significantly affected by crude oil prices to a greater degree than that of technology and transportation stocks. Later, the breakpoint regression is used to estimate regime-dependent coefficients. The most important findings of this study can be enumerated as follows:

1. The Perron and Yabu (2009) test indicates that there is at least one regime shift in each series under consideration.
2. The Carrion-i-Silvestre et al. (2009) unit root tests show that all the series are integrated of the same order, I(1).
3. Since all the series are I(1), the existence of any cointegrating relationship can be examined by using cointegration tests.
4. The Maki's (2012) cointegration tests reveal that in the presence of multiple structural breaks all of the three models are cointegrated.
5. Cointegration results confirm the existence of long-run equilibrium relationships between these stock indices, crude oil prices, short-term interest rates, and S&P500.
6. These findings indicate that crude oil prices, short-term interest rates, and S&P500 are long-run determinants of the stock prices of oil, technology, and transportation companies.

7. The DOLS results show that stocks prices of oil companies are positively and significantly affected by crude oil prices to a greater degree than that of technology and transportation stocks.
8. The results of the breakpoint regressions are almost in line with the DOLS results, but they give us a hint about how the oil price exposure of these companies changing over time as it takes multiple regimes into account and provides regime-dependent coefficients.
9. Time-varying causality results show that WTI is relatively more likely to affect the stock prices of oil, technology, and transportation companies and not vice versa.
10. It is confirmed that financial crises have a substantial ability to amplify the causal linkage between WTI and the stock indices of these companies.

4.2 Policy Implications

4.2.1 First Study

The findings of this study improve our insight about the nexus between oil price changes and equity returns of financial and non-financial subsectors. The implications of the oil price risk exposure results are important for investors, corporate executives, portfolio managers, hedge funds, and policy makers. Managers working in highly oil-sensitive subsectors should pay special attention to their hedging practices. For instance, portfolio managers, investors, and CFOs should take into account the discrepancy in oil price exposure across subsectors to optimally allocate their portfolios and find potential subsectoral hedging opportunities. It is believed that the present study will generate further research interests to investigate the oil price risk exposure of industry subsectors in other countries.

Specifically, it can lead to studies examining the oil price risk exposure of industry subsectors in developed countries and developing countries, and in oil exporting and non-oil exporting countries.

4.2.2 Second Study

The results of the DOLS long-run models show that crude oil prices positively and significantly influence technology stocks. This points out that even high oil prices have the ability to enhance the financial performance of technology companies as they shift toward inventing new energy conserving and green products. Consequently, if technology companies are prosperous in achieving these demands, this will also improve their financial performances.

It is believed that the implications of this study are important and valuable for portfolio managers, CFOs, financial managers, and hedge funds. They have to pay special attention to the oil prices exposure of their companies or portfolios as the degree of causality and cross-market spillover tend to be amplified between these markets in the event of financial crises.

REFERENCES

Aaltonen, J., & Östermark, R. (1997). A rolling test of Granger causality between the Finnish and Japanese security markets. *Omega*, 25, 635–642.

Aggarwal, R., Akhibe, A., & Mohanty, S. (2012). Oil price shocks and transportation firm asset prices. *Energy Economics,* 34, 1370–1379.

Apergis, N., & Miller, S.M. (2009). Do structural oil-market shocks affect stock prices? *Energy Economics*, 31, 569–575.

Appenzeller, T. (2004). The end of cheap oil. *National Geographic*, 205, 82–109.

Arouri, M., & Nguyen, D.K. (2010). Oil prices, stock markets and portfolio investment: evidence from sector analysis in Europe over the last decade. *Energy Policy*, 38, 4528–4539.

Bai, J., & Perron, P. (2003). Computation and analysis of multiple structural change models. *Journal of Applied Economics*, 18, 1–22.

Bai, J., & Perron, P. (2006). Multiple structural change models: A simulation analysis. *Econometric Theory and Practice: Frontiers of Analysis and Applied Research*. D. Corbae, S. N. Durlauf, and B. E. Hansen (eds.), pp. 212-237. Cambridge University Press, New York.

Billio, M., Lo, A., Getmansky, M., & Pelizzon, L. (2012). Econometric Measures of Connectedness and Systemic Risk in the Finance and Insurance Sectors. *Journal of Financial Economics*, 104, 535–559.

Black, F. (1976). Studies of stock price volatility of changes. *American Statistical Association Journal*, 21, 177–181.

Bollerslev, T, Engle, R.F., & Nelson, D.B. (1994). ARCH Models, in the *Handbook of Econometrics*, Vol IV, ed. R. F. Engle & D. McFadden, Amsterdam, North Holland, 2959-3038.

Bollerslev, T. (1986). Generalized autoregressive conditional heteroskedasticity. *Journal of Econometrics*, 31, 307–327.

Boyer, M.M., & Filion, D. (2007). Common and fundamental factors in stock returns of Canadian oil and gas companies. *Energy Economics*, 29, 428–453.

Bredin, D., & Elder, J. (2011). US Oil Price Exposure: The Industry Effects, *Working Papers* 201107, Geary Institute, University College Dublin.

British Petroleum. (2014). *BP Statistical Review of World Energy*.

Brooks, C. (2014). *Introductory Econometrics for Finance*. Cambridge University Press.

Cabedo, J.D., & Moya, I. (2003). Estimating oil price Value at Risk using the historical simulation approach. *Energy Economics*, 25, 239–253.

Carhart, M.M. (1997). On persistence in mutual fund performance. *Journal of Finance*, 52, 57–82.

Carrion-i-Silvestre, J.L., & Sansó, A. (2006). Testing the Null of Cointegration with Structural Breaks. *Oxford Bulletin of Economics and Statistics*, 68, 623–646.

Carrion-i-Silvestre, J.L., Kim, D., & Perron, P. (2009). GLS-based Unit Root Tests with Multiple Structural Breaks under both the Null and the Alternative Hypotheses. *Econometric Theory*, 25, 1754–1792.

Chang, C., McAleer, M., & Tansuchat R. (2013). Conditional correlations and volatility spillovers between crude oil and stock index returns. *North American Journal of Economics and Finance*, 25, 116–138.

Chen, N.F. (1991). Financial investment opportunities and the macroeconomy. *Journal of Finance,* 46, 529–554.

Chen, N.F., Roll, R. & Ross, S.A. (1986). Economic forces and the stock market. *Journal of Business*, 59, 383–403.

Cheung, Y., Ng, L. (1996). A causality-in-variance test and its application to financial market prices. *Journal of Econometrics,* 72, 33–48.

Christie, A.A. (1982). The Stochastic Behavior of Common Stock Variances: Value, Leverage and Interest Rate Effects. *Journal of Financial Economics*, 10, 407–432.

Clements, M.P., & Hendry, D.F. (1995). Forecasting in cointegrated system. *Journal of Applied Econometrics*, 10, 127–146.

Click, R.W. (2001). Foreign exchange and oil price exposure in the long run: an application to oil company value. Global Management Research. *Working Paper Series*, GMRWPS 01-07. George Washington University.

Cogley, T., & Sargent, T. (2001). Evolving post World War II US inflation dynamics. *NBER Macroeconomic Annuals*, 16, 331–373.

Cologni, A., & Manera, M. (2008). Oil prices, inflation and interest rates in a structural cointegrated VAR model for the G-7 countries. *Energy Economics*, 38, 856–888.

Cont, R. (2001). Empirical properties of asset returns: stylized facts and statistical issues. *Quantitative Finance*, 1, 223–236.

Cunado, J., & Perez de Garcia, F. (2005). Oil prices, economic activity and inflation: evidence for some Asian countries. *The Quarterly Review of Economics and Finance*, 45, 65–83.

Darby, M.R. (1982). The price of oil and world inflation and recession. *American Economic Review*, 72, 738–751.

Demirer, R., Jategaonkar, S.P., & Khalifa, A.A.A. (2015). Oil Price Risk Exposure and the Cross-Section of Stock Returns: The Case of Net Exporting Countries. *Energy Economics,* 49, 132-140.

Dhaoui, A., & Khraief, N. (2014). Empirical linkage between oil price and stock market returns and volatility: evidence from international developed markets, Discussion Paper No.2014-12. *Economics: The Open-Access, Open Assessment E-Journal*.

Duffie, D., & Pan, J. (1997). An overview of the Value at Risk. *Journal of Derivatives*, 4, 7–49.

Elyasiani, E., Mansur, I., & Odusami, B. (2011). Oil price shocks and industry stock returns. *Energy Economics,* 33, 966–974.

Embrechts, P., Klüppelberg, C., & Mikosch, T. (1997). *Modeling Extremal Events for Insurance and Finance*. Springer, New York.

Engle, R.F. (1982). Autoregressive conditional heteroskedasticity with estimates of the variance of United Kingdom inflation. *Econometrica*, 50, 987–1007.

Engle, R.F., & Manganelli, S. (2004). CAViaR: Conditional autoregressive value at risk by regression quantiles. *Journal of Business and Economic Statistics,* 22, 367–381.

Engle, R.F., & Yoo, B.S. (1987). Forecasting and testing in cointegrated system. *Journal of Econometrics*, 35, 143–159.

Fama, E.F., & French, K.R. (1993). Common risk factors in the returns on stocks and bonds. *Journal of Financial Economics,* 33, 3–56.

Fama, E.F., & French, K.R. (2015). A five-factor asset pricing model. *Journal of Financial Economics*, 116, 1–22.

Fan, Y. (2000). VaR methodology and its application in stock market risk analysis. *Chinese Journal of Management Science*, 8, 26–30.

Fan, Y., Wei, Y.M., & Xu, W.X. (2004). Application of VaR methodology to risk management in the stock market in China. *Computers & Industrial Engineering*, 46, 383–388.

Fan, Y., Zhang, Y.J., Tsai, H.T., & Wei, Y.M. (2008). Estimating 'Value-at-Risk' of crude oil price and its spillover effect using the GED–GARCH approach. *Energy Economics,* 30, 3156–3171.

Feng, C.S., Wu, J.C., & Jiang, F. (2004). To compute the oil market value at risk by applying semi-parametric approach. *Journal of Hubei University (Natural Science Edition)*, 26, 213–217.

Gisser, M., & Goodwin, T.H. (1986). Crude oil and the macroeconomy: Tests of some popular notions. *Journal of Money, Credit and Banking*, 18, 95–103.

Gogineni, S. (2010). Oil and the stock market: An industry level analysis. *The Financial Review*, 45, 995-1010.

Granger, C.W.J. (1969). Investigating causal relations by econometric models and cross-spectral methods. *Econometrica*, 37, 424–438.

Granger, C.W.J. (1980). Testing for causality: A personal view. *Journal of Economic Dynamics and Control*, 2, 329–352.

Grootveld, H. & Hallerbach, W. (1999). Variance vs downside risk: Is there really that much difference? *European Journal of Operational Research*, 114, 304-319.

Hamilton, J.D. (1983). Oil and the macroeconomy since World War II. *Journal of Political Economy*, 91, 228–248.

Hamilton, J.D. (2009). Understanding crude oil prices. *Energy Journal*, 39, 179–206.

Hammoudeh, S., & Li, H. (2004). Risk-return relationships in oil-sensitive stock markets. *Finance Letters*, 2, 10–15.

Hartz, C., Mittnik, S., & Paolella, M. (2006). Accurate value-at-risk forecasting based on the normal-GARCH model. *Computational Statistics and Data Analysis*, 51, 2295–2312.

Haugh, L. (1976). Checking the independence of two covariance stationary time series: a univariate residual cross-correlation approach. *Journal of the American Statistical Association,* 71, 378–385.

He, C., Terasvirta, T. & Malmsten, H. (2002). Moment structure of a family of first-order exponential GARCH models. *Econometric Theory,* 18, 868–885.

Hendricks, D. (1996). Evaluation of value at risk modeling using historical data. *Economic Policy Review*. Federal Reserve Bank of New York.

Henriques, I., & Sadorsky, P. (2008). Oil prices and the stock prices of alternative energy companies. *Energy Economics*, 30, 998–1010.

Hill, J.B. (2007). Efficient tests of long-run causation in trivariate VAR Processes with a rolling window study of the money-income relationship. *Journal of Applied Econometrics*, 22, 747-765.

Hilton, G.A. (2003). *Value-at-risk, Theory and Practice*. New York.

Hoffman, D.L., & Rasche, R.H. (1996). Assessing forecast performance in a cointegrated system. *Journal of Applied Econometrics*, 11, 495–517.

Hong, Y. (2001). A test for volatility spillover with application to exchange rates. *Journal of Econometrics*, 103, 183–224.

Hong, Y., Liu, Y. & Wang, S. (2009). Granger Causality in Risk and Detection of Extreme Risk Spill-over between Financial Markets. *Journal of Econometrics,* 150, 271–287.

Huang, R.D., Masulis, R.W., & Stoll, H.R. (1996). Energy shocks and financial markets. *Journal of Futures Markets*, 16, 1–27.

Insurance Information Institute. (2015). *Catastrophes: Insurance Issues*. Retrieved from http://www.iii.org/issue-update/catastrophes-insurance-issues

International Energy Agency (IEA), Medium Term Oil Market Report. (2013). Retrieved from http://www.IEA.org

Jin, Y., & Jorion, P. (2006). Firm value and hedging: evidence from U.S. oil and gas producers. *Journal of Finance*, 61, 893–919.

Johansen, S. (1988). Statistical Analysis of Cointegration Vectors. *Journal of Economic Dynamics and Control*, 12, 231-254.

Jones, C., & Kaul, G. (1996). Oil and the stock markets. *Journal of Finance*, 51, 463–491.

Kalman, R.E. (1960). A new approach to linear filtering and prediction problems. *Journal of Basic Engineering*, 82, 35–45.

Kilian, L. (2008). The economics effects of energy price shocks. *Journal of Economic Literature*, 46, 871–909.

Kilian, L. (2009). Not all oil price shocks are alike: disentangling demand and supply shocks in the crude oil market. *American Economic Review*, 99, 1053–1069.

Kilian, L., & Park, C. (2009). The impact of oil price shocks on the U.S. stock market. *International Economic Review*, 50, 1267–1287.

Kling, J.L. (1985). Oil Price Shocks and Stock-Market Behavior. *Journal of Portfolio Management*, 12, 34–9.

Kupiec, P.H. (1995). Techniques for verifying the accuracy of risk measurement models. *Journal of Derivatives*, 3, 73–84.

Lee, J., & Strazicich, M.C. (2003). Minimum Lagrange Multiplier Unit Root Test with Two Structural Breaks. *The Review of Economics and Statistics*, 85, 1082–1089.

Levine, R. (1997). Financial Development and Economic Growth: Views and Agenda. *Journal of Economic Literature*, 35, 688–726.

Lintner, J. (1965). The valuation of risk assets and the selection of risky investments in stock portfolios and capital budgets. *Review of Economics and Statistics*, 47, 13–37.

Loudon, G. (2001). Financial risk exposures in the airline industry: Evidence from Australia and New Zealand. *Australian Journal of Management,* 29, 295–316.

Maki, D. (2012). Tests for Cointegration Allowing for an Unknown Number of Breaks. *Economic Modelling*, 29, 2011–2015.

Mikosch, T. & Rezapour, M. (2013). Stochastic volatility models with possible extremal clustering. *Bernoulli*, 19, 1688-1713.

Miller, J.I., & Ratti, R.A. (2009). Crude oil and stock markets: Stability, instability and bubbles. *Energy Economics,* 31, 559-568.

Mohanty S., Nandha, M., Turkistani, A., & Alaitani, M. (2011). Oil price movements and stock market returns: Evidence from Gulf Cooperation Council (GCC) countries. *Global Finance Journal*, 22, 42-55.

Mohanty, S., & Nandha, M. (2011a). Oil risk exposure: the case of the U.S. oil and gas sector. *Financial Review*, 46, 165–191.

Mohanty, S., & Nandha, M. (2011b). Oil shocks and equity returns: an empirical analysis of the US transportation sector. *Review of Pacific Basin Financial Markets and Policies,* 14, 101–128.

Mohanty, S., Akhigbe, A., Al-Khyal, T. & Bugshan, T. (2013). Oil and stock market activity when prices go up and down: the case of the oil and gas industry. *Review of Quantitative Finance and Accounting*, 41, 253–272.

Mohanty, S., Nandha, M., Habis, E., & Juhabi, E. (2014). Oil price risk exposure: The case of the U.S. Travel and Leisure Industry. *Energy Economics*, 41, 117–124.

Mork, K.A. (1994). Business cycles and the oil market. *Energy Journal,* 15 (Special Issue).

Mossin, J. (1966). Equilibrium in a Capital Asset Market. *Econometrica*, 35, 768–83.

Moya-Martínez, P., Ferrer-Lapeña, R. & Escribano-Sotos, F. (2014). Oil price risk in the Spanish stock market: An industry perspective. *Economic Modelling*, 37, 280–290.

Nandha, M., & Brooks, R. (2009). Oil prices and transport sector returns: an international analysis. *Review of Quantitative Finance and Accounting*, 33, 393–409.

Nandha, M., & Faff, R. (2008). Does oil move equity prices? A global view. *Energy Economics*, 30, 986–997.

Nelson, D.B. (1990). ARCH models as diffusion approximations. *Journal of Econometrics*, 45, 7–38.

Ng, S., & Perron, P. (2001). Lag Length Selection and the Construction of Unit Root Tests with Good Size and Power. *Econometrica*, 69, 1519–1554.

Organization of the Petroleum Exporting Countries. (2014). *OPEC Annual Statistical Bulletin*.

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

Perron, P. (1989). The great crash, the oil price shock and the unit root hypothesis. *Econometrica*, 57, 1361–1401.

Perron, P., & Yabu, T. (2009). Testing for shifts in trend with an integrated or stationary noise component. *Journal of Business & Economic Statistics*, 27, 369–396.

Racicot, F.E. & Theoret, R. (2016). Macroeconomic shocks, forward-looking dynamics, and the behavior of hedge funds. *Journal of Banking and Finance,* 62, 41–61.

Rajan, R. (2010). *Fault Lines: How Hidden Fractures Still Threaten the World Economy*. Princeton, NJ, Princeton University Press.

Rajgopal, S. (1999). Early evidence on the informativeness of the SEC's market risk disclosures: the case of commodity price risk exposure of oil and gas producers. *Accounting Review*, 74, 251–280.

Reboredo, J.C., & Rivera-Castro, M.A. (2014). Wavelet-based evidence of the impact of oil price on stock returns, *International Review of Economics and Finance*, 29, 145–176.

Sadorsky, P. (1999). Oil price shocks and stock market activity. *Energy Economics*, 21, 449-469.

Sadorsky, P. (2001). Risk factors in stock returns of Canadian oil and gas companies. *Energy Economics*, 23, 17–28.

Sadorsky, P. (2003). The Macroeconomic determinants of technology stock price volatility. *Review of Financial Economics*, 12, 191–205.

Scholtens, B., & Yurtsever, C. (2012). Oil price shocks and European industries. *Energy Economics*, 34, 1187–1195.

Schwert, G.W. (1989). Business Cycles, Financial Crises, and Stock Volatility. *Carnegie-Rochester Conference Series on Public Policy*, 39, 83-126.

Sharpe, W. F. (1964). Capital asset prices: A theory of market equilibrium under conditions of risk. *Journal of Finance*, 19, 425–442.

Sims, C. (1972). Money, income and causality. *American Economic Review*, 62, 540–552.

Sorensen, L. Q. (2009). Oil price shocks and stock return predictability. *Bergen Meetings Paper*. EFA 2009.

Stock, J., & Watson, M.W. (1993). A simple estimator of cointegrating vectors in higher order integrated systems. *Econometrica*, 61, 783-820.

Tan, K.H., & Chan, I.L. (2003). Stress testing using VaR approach: a case for Asian currencies. *Journal of International Financial Markets*, 13, 39–55.

Tsai, C. (2015). How do U.S. stock returns respond differently to oil price shocks pre-crisis, within the financial crisis, and post-crisis? *Energy Economics*, 50, 47-62.

Wang, X., & Zhang, C. (2014). The impacts of global oil price shocks on China′s fundamental industries. *Energy Policy*, 68, 394–402.

Wei, C. (2003). Energy, the Stock Market, and the Putty-Clay Investment Model. *American Economic Review*, 93, 311–23.

Westerlund, J., & Edgerton, D. (2006). New Improved Tests for Cointegration with Structural Breaks. *Journal of Time Series Analysis,* 28, 188–224.

Wintenberger, O. (2013). Continuous invertibility and stable QML estimation of the EGARCH(1,1) model. *Scandinavian Journal of Statistics,* 40, 846-867.

Wu, C.-C., Chung, H., & Chang, Y.-H. (2012). The economic value of co-movement between oil price and exchange rate using copula-based GARCH models. *Energy Economics,* 34, 270-282.

Zakoian, J.M. (1994). Threshold heteroskedastic models. *Journal of Economic Dynamics and Control,* 18, 931–995.

Zivot, E., & Andrews, D.W.K. (1992). Further evidence on the great crash, the oil-price shock, and the unit-root hypothesis. *Journal of Business and Economic Statistics*, 10, 251–270.