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Risikofaktorsensitiviter i amerikanske olje- og gasselskaper - En regimeskifttilnærming

Risk Factor Sensitivities of U.S. Oil and Gas Companies – A Regime Switching Approach

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The institution and supervisor is not responsible for the theories and methods used, nor the results and conclusions drawn, through the approval of the thesis.

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Sammendrag

Vi estimerer risikofaktorsensitivitetene til 66 amerikanske olje- og gasselskaper i perioden januar 2000 til desember 2015. Vi bruker Fama og French sin 3-faktor modell utvidet med olje-, gass-, rente- og VIX faktor. Tidligere studier av olje- og gassindustrien har funnet asymmetri i faktorsensitivitetene, derfor ønsker vi å forklare denne ikke-lineære oppførselen til aksjeavkastningene. Ved å bruke en Markov «switching» regresjon finner vi at markeds-, oljepris- og gassprissensitivitetene er regimeavhengig.

Eksponeringen mot oljeprisen og markedsfaktoren er positiv og signifikant, men det er betydelige forskjeller i størrelsen på disse. Oljeservicesektoren har den høyeste sensitiviteten mot både markeds- og oljefaktoren i høyvolatilitetsregimet. Den integrerte olje- og gassektoren har en lavere eksponering mot oljeprisen i høyvolatilitetsregimet sammenlignet med lavvolatilitetsregimet. Lete- og produksjonssektoren har en stabil sensitivitet mot oljeprisen i begge regimer. Videre finner vi at de har høyere eksponering mot oljefaktoren enn den integrerte olje- og gassektoren og rørlinjesektoren. De andre risikofaktorene i modellen vår varier også i størrelse, fortegn og signifikans. Dette indikerer at regimene, selskapene og undersektorene i den amerikanske olje- og gassindustrien er heterogene.

Sannsynligheten for å være i enten et høy- eller lavvolatilitetsregime sammenfaller stort sett med lav- og høykonjunkturene i økonomien. Unntaket er for de oljeproduserende selskapene hvor sannsynligheten for å være i et høyvolatilt regime i de siste årene har fulgt oljeprisen. De integrerte olje- og gasselskapene følger ikke denne trenden. Dette indikerer et asymmetrisk forhold mellom høy- og lavkonjunkturer og avkastningen til den amerikanske olje- og gassektoren. Resultatene våre har betydning for hedging og risikostyring både i oljeindustrien og blant private og institusjonelle investorer. Forskningen vår bidrar med bevis for asymmetri i risikofaktorsensitiviteter.

Abstract

We estimate the excess return of 66 U.S. oil and gas companies' sensitivities towards risk factors during the period from January 2000 to December 2015. We use the Fama-French 3 factor model augmented with the oil and gas price, an interest rate factor and VIX. Previous studies of the oil and gas industry have found asymmetry in the risk sensitivities. This paper seeks to explain this nonlinear behaviour of stock returns. By using a Markov switching regression to estimate the coefficients of the regression equation, we find that the market, oil price and gas price sensitivities are regime dependent.

The oil price and market risk exposure of U.S. oil and gas companies are positive and significant, however, there are considerable differences in the size of the sensitivities. We find the equipment and services subsector to have the highest risk exposure towards both the market factor and the oil price factor in the high volatility regime. The integrated oil and gas subsector has a dampened exposure towards the oil price in the high volatility regime compared to the low volatility regime. While the exploration and production subsector has a stable exposure towards the price of oil in both regimes. Furthermore, we find that the exploration and production subsector has a higher risk exposure towards the oil factor than integrated oil and gas and the pipeline subsector. The other factors in our model also vary in magnitude, sign and significance, which indicate that the regimes, firms and subsectors are non-homogenous.

The probability of being either in a high or low volatility regime coincides for most part with the business cycle. All though in recent years for oil producing companies, the probability seems to follow the oil price. Integrated oil and gas companies do not follow this trend. This indicates an asymmetric relationship between the business cycle and stock returns in the U.S. oil and gas sector. Our results have implications for hedging and risk management, for decision makers in the industry and both private and institutional investors. We also further contribute to the evidence of asymmetry in risk sensitivities.

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1. Introduction

Oil price movements are powerful events. They can spur economic growth and cause economic recessions. Oil is used both as an energy source and as input for the manufacturing of goods. This is in contrast to the beginnings of the industry. “Colonel” E.L. Drake drilled the first oil well on August 27, 1859 (Yergin, 2011). At that time, oil was harvested in pits and refined into kerosene that was used for illumination. Petroleum on the other hand, was considered waste and most of the time dumped. Today, petroleum is one of the main energy sources in the modern economy. The transport segment has been especially tied to oil consumption because oil’s high energy density cannot be matched by other sources.

The start of this millennium has seen both an economic growth period and more recently a period of decline in growth. The oil price has been no exception to this general trend in financial data. Today we are experiencing a 13-year low in crude oil prices. This is in contrast to the peak in July 2008, when oil was at USD 145 a barrel. In this cyclical environment, knowing the exposure stock returns have to risk factors is important both for managers and investors. What risk factors drive stock returns is of considerable interest in both academic and business circles.

Most researchers use linear models to explain stock returns, even though evidence of asymmetric sensitivities towards common risk factors is abundant in the literature[1]. This is why we want to use a nonlinear model to explain stock returns in the oil and gas sector. By allowing the betas of our regression model to be regime dependent, we are taking nonlinearities in our data into consideration. To our knowledge this is the first study to apply a regime switching model on a data set on both the firm and subsector level of the U.S. oil and gas industry.

We assume that the volatility of stock returns in the U.S. oil and gas sector switches between two states, a high and a low volatility regime. However, it is worth noting that the regimes are given endogenously. Previous studies propose definitions of what regimes are. Hamilton (1989) classifies two economic regimes, one with a positive growth rate and one with a

[1] Both risk factor studies of the oil and gas industry and more general studies on the stock market, using regime switching models, find nonlinear characteristics such as volatility clustering, fat-tail distributions and asymmetric relations, e.g. Mohanty and Nandha (2011), Tjaaland et al. (2015), Ramos and Veiga (2011), Reboredo (2010), Gu (2005), Morana (2001), Wilson, Aggarwal and Inclan (1996) and Zou and Chen (2013).

negative growth rate. Li (2007) suggests two regimes that imply high or low uncertainty in the stock markets. Abdymomunov and Morley (2011) use a Markov switching regression with two states, which they identify as a high and a low volatility regime.

Analysis at the firm level is important due to subsector results being aggregated and thus might conceal the impact oil price shocks, gearing and other characteristics have on individual stock returns. Furthermore, by allowing the regression coefficients to be regime dependent, we seek to illustrate that companies have different risk exposures both within subsectors and across economic regimes. If they are regime dependent, this represents a risk that managers should take into consideration in investment, financing and operational decisions. This can in turn lead to different hedging decisions for different companies. Our results should be of interest for both individual and institutional investors, as well as risk managers and decision makers in the oil industry.

Our research extends the existing literature in the following ways: to our knowledge our study is the first to use a Markov switching regression to investigate whether the risk factor sensitivities of oil companies in the U.S. vary across regimes. Our model includes a VIX factor, which we have not seen other studies use in explaining returns in the oil and gas industry. We are also the first to use the Fama and French (1992) factors on a sample which includes Royalty Trusts[2]. We ask the following research questions:

1. How do oil price shocks affect the stock returns of U.S. oil and gas companies?
2. Are the effects of oil price shocks on returns the same for different subsectors?
3. Does the risk exposure vary across firms and economic regimes?

We find that the returns of U.S. oil and gas companies are positively impacted by hikes in the oil price for both the high and low volatility regimes. The crude price influences Royalty Trusts and the oil equipment and services subsector strongest in the high volatility regime, while it has a stable influence on the exploration and production subsector in both regimes. The oil equipment and services subsector has the highest oil beta of 0.4631 in the high volatility regime. We also find that the exploration and production subsector, along with

[2] Royalty Trusts are asset-spesific types of investment trusts distributing directly to beneficiaries. The beneficiaries escape the corporate-level taxation. The trust interest is marketable and larger ones are traded on stock exchanges (Langbein, 1997).

Royalty Trusts have a higher oil price risk exposure than the integrated oil and gas and the pipeline subsectors. Furthermore, the integrated subsector has a dampened risk exposure towards the crude factor in the high volatility regime, compared to the low volatility regime. The market factor is in general positive and with high values for all subsectors, except for pipelines and Royalty Trusts in the high volatility regime, where the effect is significantly dampened compared to the low volatility regime. We also find, on the subsector level, that the equipment and services has the highest exposure towards the market in the high volatility regime, while in the low volatility regime it has the second lowest exposure. Our results reveal that these risk exposures vary across economic regimes for both firms and subsectors. Furthermore, we find that the oil price has a greater influence on returns than the price of natural gas. The intercepts of our regression are low and insignificant, which indicate that the factors in our regression help explain much of the variation in returns of the U.S. oil and gas companies.

The probabilities of being in the low or the high volatility regime seem to coincide with the business cycle, all though in recent years the probabilities for oil producing companies seem to follow the oil price. Interestingly the integrated oil and gas companies do not enter the high volatility state with the recent oil price decline. This indicates that there is an asymmetric relationship between the business cycle and the stock returns of U.S. oil and gas companies, and that the subsectors are non-homogenous. Our study should be of interest for risk managers, decision makers in the industry and to both private and institutional investors. Our paper also contributes with evidence of asymmetry in risk sensitivities. The usage of a Markov switching regression on stock returns is shown to have promising results, in both subsector and firm level analysis. We encourage further research in applying the method on other sectors and markets.

Our paper is organized as follows: Section 2 covers the relevant literature, section 3 covers our methodology and theory on the Markov switching regression, while section 4 highlights the data. Section 5 presents the empirical results and section 6 concludes our study.

2. Literature Review

Previous studies have found asymmetry in the time-series of stock returns and the risk factors sensitivities of these. As opposed to earlier econometric studies of the oil and gas industry, we allow the regression coefficients to vary over time. To our knowledge there are no previous studies that use regime switching models when looking at stock returns of the oil and gas industry on both the firm and subsector level.

The study that first employed a Markov switching regression on financial data was Hamilton (1989). He used the method on postwar U.S. real GNP data. His results showed that the likelihood of being in either a positive or negative growth period corresponded closely to the NBER[3] dating of business cycles. The advantage over conventional sample splitting is that the probability of being in a given regime is determined endogenously by the data (Hamilton, 1994). Furthermore, the model can pick up characteristics such as fat tails, skewness and excess kurtosis (Ang and Timmermann, 2011).

The regime switching literature can roughly be divided into two categories; studies that focus on the theoretical aspect of the method, and studies that look at empirical application. An example of the theoretical work is Gray (1996) who developed a regime switching model with time-varying transition probabilities to model the short-term interest rate. Among the empirical studies are Chen (2009) who uses a regime switching model, structural finite mixture regression models and a logistic smooth transition regression to investigate the relationship between spot prices in the British electricity market and its underlying driving factors. Reboredo (2010) uses a regime switching model to look at nonlinear effects of oil shocks on stock returns. The study finds the oil price to have a negative and significant impact on stock returns in one state, while in the other state the effect is dampened. Zou and Chen (2013) use a similar method, and find that a drop in the WTI crude price is more volatile than an increase in the WTI crude price, indicating an asymmetric tail relationship. Balcilar et al. (2015) find that positive oil shocks have a negative influence on the S&P 500 in the high volatility regime, while no relation is found in the low volatility regime. Naifar and Dohaiman (2013) also find support for regime dependency in the relation between stock markets and oil market volatility.

[3] The National Bureau of Economic Research.

Schaller and Van Norden (1997) look at stock market returns from January 1929 to December 1989. They find evidence for switching behavior in both the mean and the variance of U.S. stock market returns. Abdymomunov and Morley (2011) use a regime switching version of the CAPM to investigate whether betas of book-to-market and momentum portfolios are time varying across stock market returns. They find that when allowing risk premiums to vary between a low and a high volatility regime, the time varying betas explain more of the variation in portfolio returns than the unconditional CAPM. Gu (2005) looks at asymmetric risk loadings in the cross section of stock returns, by using regime switching versions of the CAPM and Fama-French three-factor model. The study finds that there is asymmetry in factor loadings. Other papers also support these findings for the oil and gas sector by using OLS regression, e.g. Mohanty and Nandha (2011), Tjaaland et al. (2015) and Sadorsky (2001). Our study is closest in method to Gu (2005), however, we extend the analysis to the subsector and firm level.

Faff and Brailsford (1999) use a two factor linear model augmented with a market factor and oil price adjusted for exchange rate. They find that the Australian oil and gas sector has a significant and positive sensitivity towards the oil price factor. Other empirical studies have also found the oil price to be a significant factor in explaining stock returns in different countries[4] and sectors[5]. Sadorsky (2001) uses a multifactor model that incorporates exchange rate, oil price, interest rate and a market factor. The study concludes that these factors have a significant impact on stock price returns for Canadian oil and gas companies. Boyer and Filion (2007) support his findings and, in addition, they augment their model with a natural gas factor, which they also find to be statistically significant. They also find that stock returns in the oil and gas industry may differ based on the firm's ability to pass on higher oil costs to their customers. Thus, minimizing the exposure of higher fuel costs to their cash flows. Ramos and Veiga (2011) find that a raise in oil prices has a stronger impact on returns in the

[4] Cong et al. (2008) find that the oil price has significant impact on some of the oil firms in China, using a multivariate vector auto regression. El- Sharif et al. (2005) find that the relationship between oil price and UK oil and gas firm's equity returns are positive and often significant by using a multifactor model. Mohanty et al. (2011) examine the relationship between crude oil and stock returns in Gulf Cooperation Council countries, both on sector and country level. Most countries show significant positive exposure, however, the risk factor has asymmetric effects on equity market returns on both sector and country level.

[5] Aggarwal et al. (2012) examine the effect of an oil price change in the transportation sector by using daily data. The study concludes that transportation firm returns are negatively and asymmetrically influenced by a change in oil prices. Mohanty et al. (2014) examine the impact oil price shocks have on the stock returns of U.S. travel and leisure industry, using the Fama-French-Carhart's four-factor model augmented with an oil price risk factor. They conclude that oil price has significant effect on returns of the industry, however, the impact varies across both time and the subsectors.

oil industry than a drop in oil prices. They do not find any other commodity with the same asymmetric relationship; they rather seem to have the opposite relation. They also find that oil price is a globally priced risk factor in the oil industry.

Mohanty and Nandha (2011) use the Fama-French-Carhart's four-factor model augmented with oil price and an interest rate factor. They find evidence for the Fama-French factors and the oil price to be significant determinants of stock returns in the U.S. oil and gas sector. They also investigate the sample over time and across firms and subsectors, and find asymmetry in factor loadings. Regarding the SMB factor, empirical studies have shown that small firms have higher returns and that large firms have lower returns than predicted by theory, e.g. Banz (1981) and Fama and French (1992).

Basher and Sadorsky (2006) examine the relationship between oil price risk and returns in emerging stock markets by using a multi-factor model. The results show that oil price risk impacts stock returns in emerging markets. Osmundsen et al. (2006) look at the relationship between market valuation and both financial and operational indicators, using panel data for 14 international oil and gas firms from 1990 to 2003. The study concludes that changes in a firm's valuation are mainly caused by oil price, production of oil and gas and reserve replacement. Hammoudehet et al. (2004) examine cointegration between U.S. oil price markets and stock indices of the oil sectors by using daily data. They conclude that exploration firms take their cues from oil markets. Nandha and Faff (2008) estimate the effect of oil price shocks on stock markets at the industry level. They find that a raise in oil prices has a negative effect on stock returns for all sectors, except mining and the oil and gas industry. Mohanty et al. (2012) find that there is an asymmetric relationship between oil price changes and the returns of oil and gas firms, market betas, oil betas and return variances. In addition, they find that firm characteristics such as firm size and book-to-market matter in determining the effect oil price shocks have on the returns of oil and gas firms.

Talbot et al. (2013) investigate the impact the theoretical drivers, which Tufano (1998) found for the gold industry, have on oil industry stock returns in North America. Strong evidence is found for leverage and market value, which are closely related to firm size, to have a positive association with the oil beta of North American oil stocks. Although they find statistical significance for variables connected to exogenous firm characteristics and financing decisions, this is found to have less compelling economic significance. Hong and Sakar

(2008) find that an increase in interest rates has a positive impact on oil betas. They theorize that an increase in interest rates decreases the asset value through the discount rate going up. This would bring a firm closer to default and therefore increase the sensitivity of equity values.

Ang et al. (2006) investigate the cross section between volatility and expected returns. They find that stocks with high sensitivity to systematic volatility risk and stocks with high idiosyncratic volatility have lower average returns. French, Schwert and Stambaugh (1987) and Campbell and Hentschel (1992) find that periods of high volatility often coincide with economic downturns. Bakshi and Kapadia (2003) find that assets with high exposure towards market volatility provide a hedge against market downturns.

3. Methodology

This section is built on Hamilton (1994) and gives an introduction to modeling of time series with changes in regime.

3.1 Regime Switching

The idea that regimes are conditional on various structures in the economy was first presented by Hamilton (1989). The Markov switching model, also known as the regime switching model, is a nonlinear time series model. There can be several reasons for regime switching. Some might be recurring, such as recessions and expansions, and some might be permanent, like breaks. Some examples are changes in government policies, changes in financial expectations or special events such as war or financial panic (Hamilton, 1994). Empirical data has shown ex-post that these regime switches are likely to have an effect on stocks, bonds, exchange markets and other macro variables. The model uncovers complex patterns, since it allows for nonlinearity and a switch between different structures. However, what factors drive regime switching is an issue the model fails to answer. The model assumes that the regime itself is hidden but is determined by an underlying unobservable stochastic process, which follows a first-order Markov chain (Chen 2009). The regimes are found as the maximum likelihood estimate of the following equation:

$$\mathcal{L}(\theta) = \sum_{t=1}^{T} \log f(y_t;\ \theta) \tag{1}$$

Where θ is a vector that contains the coefficients of the regression.

3.2 Markov Chains

S_t is a random variable that indicates what state or regime the regression coefficients comes from. It follows a first-order Markov chain. It is assumed that the probability of s_t being of an integer value, j, depends only on the previous value, s_{t-1}. An underlying assumption is that the future to a certain extent will be similar to the past:

$$P\,\{s_t = j | s_{t-1} = i, s_{t-2} = k, \dots\} = P\{s_t = j | s_{t-1} = i\} = p_{ij} \qquad (2)$$

The transition probabilities are represented by $\{p_{ij}\}_{i,j=1,2,\dots,N}$, which denotes the probability that state i is followed by state j, where j are the rows and i the columns. The transition probability model can be put in an $N \times N$- matrix, P. The sum of each column is equal to 1:

$$P = \begin{bmatrix} p_{i1} & \cdots & p_{N1} \\ \vdots & \ddots & \vdots \\ p_{iN} & \cdots & p_{NN} \end{bmatrix} \qquad (3)$$

The ith column of the matrix P, can be represented by a random (N X 1) vector, denoted ζ_t, whose jth element is equal to unity if $s_t = j$. Given $s_t = i$, the conditional expectation of ζ_{t+1} is given by:

$$E(\zeta_{t+1} | s_t = i) = \begin{bmatrix} p_{i1} \\ \vdots \\ p_{iN} \end{bmatrix} \qquad (4)$$

In the above equation, the probability p_{ij} means that for $s_t = i$, the jth factor of ζ_{t+1} is a random variable that takes the value 1. Given $s_t = i$, the vector ζ_t is equivalent to the ith column of the identity matrix I_N, which implies that:

$$E(\zeta_{t+1} | \zeta_t) = P\zeta_t \qquad (5)$$

From the above equation a first-order vector autoregression for ζ_t can represent a Markov chain in the form:

$$\zeta_{t+1} = P\zeta_t + v_{t+1} \qquad (6)$$

Where

$$v_{t+1} = \zeta_{t+1} - E(\zeta_{t+1} | \zeta_t, \zeta_{t-1}, \dots) \qquad (7)$$

The above equation is a martingale difference sequence, and v_t assumes only a finite set of values, with a mean value of zero, and cannot be forecasted based on previous states of the process.

3.3 Determining the Number of Regimes

Determining the number of regimes is an important issue with regards to the accuracy of the model. This can in turn lead to better financial forecasting and optimization of asset allocation. However, the decision is tricky, because of the regimes being an approximation to underlying states which are assumed to be unobservable. The test concerning the number of regimes cannot be done using likelihood ratio tests, because the condition of a chi-square distribution fails to hold (Hamilton, 1994). A solution is to simply fix the number of regimes, commonly two, e.g. Hamilton 1989, who describes the U.S. economy to be in either a normal state with a positive growth rate, or in a recession state, with a negative growth rate. Davies (1977), Andrews and Ploberger (1994) propose tests to overcome the problem. In addition, Hamilton (1996) proposes residual tests to determine the number of regimes. For a more extensive theoretical background, we refer to Hamilton (1994).

3.4 The Model

We incorporate Fama and French's (1992) three asset pricing factors in our model, namely a market factor, a size factor (SMB) and a book-to-market factor (HML). In addition we have augmented our model with the crude oil price, the natural gas price, an interest rate factor and a volatility factor (VIX). Our model includes seven risk factors, and can be written as follows:

$$\begin{aligned} R_{it} - R_{ft} = \alpha_{st} + \beta_{1,i,st}\left(R_{mt} - R_{ft}\right) + \beta_{2,i,st}R_{Oil,t} + \beta_{3,i,st}R_{Gas,t} + \beta_{4,i,st}R_{Int,t} \\ + \beta_{5,i,st}SMB_t + \beta_{6,i,st}HML_t + \beta_{7,i,st}Ln_{VIX,t} + \varepsilon_{i,st} \end{aligned} \quad (8)$$

Where

$$\varepsilon_{i,st} \sim N(0, \sigma_{st}^2) \quad (9)$$

St is a binary state variable that can take the value of 0 or 1 and it is assumed to follow a first-order Markov chain (see equation 2).

R_{it}-R_{ft} is the excess monthly return of stock *i* at time *t* less the return of the one month U.S. Treasury Bill. R_{mt}-R_{ft} is the excess monthly return of the S&P 500 market portfolio on day *t*. By including the market factor, we should be able to assess whether U.S. oil and gas stocks are more or less risky than the market, which is useful in hedging considerations. The sign of the beta will also tell us if the industry is pro or countercyclical. $R_{Oil,t}$ is the monthly logged return on the West Texas Intermediate (WTI) crude oil price, which is expressed in USD pr.

barrel. We have used the WTI spot Cushing, because of it being extensively used as a price reference in North America (Mohanty and Nandha, 2011). $R_{Gas,t}$ is the return on NYMEX natural gas one-month futures, which is measured in USD/MMBTU. We use the WTI oil price and NYMEX natural gas prices because derivative contracts used by firms when hedging, often use these as underlying assets (Boyer and Filion, 2007). $R_{Int,t}$ is a proxy for the interest rate factor and is calculated as the logged change in the ten-year Treasury bond yield. Since the oil industry is capital intensive, we chose to include the interest rate factor due to its importance in determining the cost of borrowing. SMB_t is the return of a portfolio that mimics the difference in returns between small and big market cap firms. HML_t is the difference between the average of monthly returns of a portfolio of high book-to-market firms and the average of a portfolio with low book-to-market firms. $Ln_{VIX,t}$ is the logarithmic transformed CBOE volatility index, which gives an estimate on expected future volatility. α is the intercept and ε are the residuals. The denotation *st* means that the risk factors, intercept and residuals are state dependent.

We let the coefficients of our regression be governed by regimes. These regimes are in turn controlled by a stochastic indicator variable, *st*, which follows a Markov chain. The coefficients of our regression are found by the maximum likelihood estimate of equation 1, subject to the constraint that the probabilities sum to one. The resulting two density distributions are representations of what we call the high and the low volatility regime. We then use these distributions to draw interference about which regime the observations most likely stems from. This produces graphs of the probability of a given observation being drawn from either regimes and also lets us calculate the expected duration of each regime. The advantage of this over regular sample splitting is that the identification of regimes is done endogenously. Furthermore, by allowing the betas to be regime dependent we are moving away from the assumptions of normally distributed data.

4. Data

Our sample contains companies within the U.S. oil and gas sector based on the Datastream Global Equity classification. All companies are traded on the NYSE and operate in the U.S. A criterion for inclusion in our sample is that the company has a complete time series of prices in our sample period, from January 2000 to December 2015. We use monthly observations (start of month) collected from Datastream, denominated in U.S. dollars. Our final sample contains 66 oil and gas companies[6] with complete data, divided into five subsectors: 31 exploration and production companies, 7 integrated oil and gas companies, 16 oil equipment and service companies, 5 pipeline companies and 7 Royalty Trusts. The subsector analysis is based on equally weighted portfolios of the companies included in our sample. In the appendix is a list of the firms in our sample (Table A1). Market, oil and gas prices, interest rate and VIX are obtained from Datastream. HML and SMB are collected from Kenneth French´s web page. The following table shows how the independent variables have been calculated.

Table 1: Measure of the Independent Variables

Variable	Measure
Excess return market	$R_{mt} - R_{ft} = ln((S\&P\ 500\ Monthly\ Return - 1\ month\ U.S.Treasury\ Bill)_t\ /\ (S\&P500\ Monthly\ Return - 1\ month\ U.S.Treasury\ Bill)_{t-1})$
Return oil price	$R_{Oil} = ln((Crude\ Oil\ WTI\ Price\ in\ USD/BBL)_t\ /\ (Crude\ Oil\ WTI\ Price\ in\ USD\ /BBL)_{t-1})$
Return natural gas price	$R_{Gas} = ln((NYMEX\ Natural\ Gas\ Price\ in\ USD/TE)_t\ /\ (NYMEX\ Natural\ Gas\ Price\ in\ USD/TE)_{t-1})$
Change in interest rate	$R_{Int} = ln((10\ year\ U.S.Treasury\ Bond\ Yield)_t\ /\ (10\ year\ U.S.Treasury\ Bond)_{t-1})$
Size	$SMB_t = 1/3\ (Small\ Value + Small\ Neutral + Small\ Growth) - 1/3\ (Big\ Value + Big\ Neutral + Big\ Growth)$
B/M	$HML_t = 1/2\ (Small\ Value + Big\ Value) - 1/2\ (Small\ Growth + Big\ Growth)$
Ln transformed VIX	$Ln_{VIX} = ln\ SPX\ Volatility\ VIX$

[6] We first included Penn Virginia Corporation in our sample, but due to asset sales and financial turmoil, the firm experienced a severe drop in share prices in 2015. This biased the data, causing one regime to be influenced solely by the event.

A priori we expect oil and gas prices to have a positive effect on returns, with this relation being stronger in market downturns. The market factor is also expected to have a positive effect on returns. The interest rate factor is expected to have a negative impact. The interest rate effect should be more prominent in market downturns, and affect smaller market cap companies to a greater extent. This is due to smaller firms having fewer assets to use as collateral, which is more important in economic downturns, when credit is scarce (Quiros and Timmermann, 2000).

Table 2 presents descriptive statistics for the companies included in our sample. We have calculated monthly logged excess return of our data, which includes 191 observations dating from January 2000 to December 2015. Out of the 66 firms, 20 show negative mean return. A possible explanation for this is the financial crisis in 2008, which hit most parts of the economy. Royalty Trusts have the highest percentage of firms with negative mean returns.

Table 2: Descriptive Statistics: Firm Level

We have used monthly data observations, from January 2000 to December 2015. Our sample contains 66 firms in the U.S. oil and gas industry: 31 in Exploration and Production, 7 Integrated Oil and Gas firms, 16 firms in Oil Equipment and Services, 5 Pipeline companies and 7 Royalty Trusts. The data is obtained from Datastream.

Company Name	Mean (%)	Min. (%)	Max. (%)	St. Dev. (%)	Skewness	Kurtosis
Exploration & Production						
ANADARKO PETROLEUM	0.5439	-41.9404	35.9771	10.3974	-0.4450	2.5638
APACHE	0.4880	-34.0757	30.4625	10.2636	-0.3019	0.7030
ATWOOD OCEANICS	0.1554	-51.4504	32.8444	12.2469	-0.4257	1.3339
CABOT OIL & GAS 'A'	1.2788	-42.5754	35.2155	11.7557	-0.3819	1.3088
CALLON PTL.DEL.	-0.3437	-166.7707	64.9088	23.2560	-1.8656	13.8202
CHESAPEAKE ENERGY	0.3567	-50.8699	49.7228	14.0426	-0.2414	1.4830
CLAYTON WILLIAMS EN.	0.7058	-59.3240	52.4698	18.0651	-0.0115	0.4464
COMSTOCK RES.	-0.1963	-86.4997	89.0973	18.6712	-0.1382	4.5215
DENBURY RES.	0.5341	-45.9104	43.7710	14.1809	-0.3883	1.6177
DEVON ENERGY	0.4110	-42.3469	25.8518	10.0792	-0.6882	1.6786
DIAMOND OFFS.DRL.	-0.2655	-30.0831	27.3604	10.4852	-0.1398	0.2317
ENERGEN	0.8822	-27.4989	21.3827	8.9305	-0.5524	1.1269
EOG RES.	1.4696	-38.1316	39.2820	10.6452	-0.1831	1.5910
EQT	0.8650	-34.1489	19.0263	8.0966	-0.7676	2.1400
GOODRICH PTL.	-1.2283	-63.5328	66.5858	21.0641	-0.3974	1.3981
MARATHON OIL	0.3159	-32.9994	25.7990	9.7132	-0.3642	0.8184
NEWFIELD EXPLORATION	0.4643	-40.3836	33.8868	11.7825	-0.5979	1.1659
NOBLE ENERGY	0.8999	-32.5819	34.6798	10.0311	-0.3481	1.6846
OCCIDENTAL PTL.	0.9260	-23.7748	27.7902	8.2800	0.0523	1.0640
PANHANDLE OIL & GAS	1.4540	-42.8279	42.3472	12.4761	-0.1985	1.6273

Company Name	Mean (%)	Min. (%)	Max. (%)	St. Dev. (%)	Skewness	Kurtosis
PARKER DRILLING	-0.2160	-69.1113	58.2418	16.3979	-0.2494	1.9542
PETROQUEST ENERGY	-0.5256	-92.2189	57.2783	19.7110	-0.5175	2.3727
PIONEER NTRL.RES.	1.3628	-67.0467	39.4420	12.8121	-0.8030	4.1615
RANGE RES.	1.2933	-32.3454	70.9783	12.6594	1.0781	6.0791
SM ENERGY	0.7046	-41.9184	33.5586	12.5551	-0.5996	1.4027
STONE ENERGY	-0.9341	-88.0559	70.2954	17.7724	-1.0362	5.9029
SUPERIOR ENERGY SVS.	0.3398	-50.0838	44.2548	13.9397	-0.6148	1.5856
SWIFT ENERGY	-1.8609	-103.5414	50.5143	19.9387	-1.2771	4.9223
TRANSOCEAN	-0.6126	-37.6503	28.9680	12.2570	-0.3416	0.4584
UNIT	0.3304	-40.9610	34.2357	12.9821	-0.4312	0.7740
VAALCO ENERGY	0.4676	-72.4925	60.9809	18.2119	0.0349	2.6747
Exploration & Production Average	0.2870	-56.2046	42.6441	13.7349	-0.4938	2.7212
Integrated Oil & Gas						
CHEVRON	0.2742	-22.9210	19.9763	6.4337	-0.1882	1.3586
CONOCOPHILLIPS	0.4613	-31.6001	21.5070	7.7632	-0.5838	1.5902
ENI SPA SPN.ADR 1:2	0.0762	-21.3240	21.9170	7.1346	-0.2907	0.2230
EXXON MOBIL	0.2458	-19.0386	15.1273	5.3242	-0.2893	1.0172
HESS	0.4802	-32.6848	29.7083	10.3190	-0.4934	1.0707
MURPHY OIL	0.3226	-24.9642	25.1527	9.2729	-0.3266	0.3892
SUNCOR ENERGY INCO.	1.1154	-51.1039	74.7250	11.7305	0.6246	9.6487
Integrated Oil & Gas Average	0.4016	-29.1359	29.1720	8.1960	-0.2026	2.1493
Oil Equipment & Services						
BAKER HUGHES	0.3795	-52.9794	25.0541	10.9072	-1.0493	3.3717
BUCKEYE PARTNERS	0.3530	-19.7359	21.3510	5.7187	-0.1677	1.5478
ENSCO CLASS A	-0.2551	-41.3554	34.5440	12.3023	-0.3095	1.1136
HALLIBURTON	0.2493	-52.2554	29.3773	12.6511	-1.1972	3.0232
HELMERICH & PAYNE	0.9307	-45.3583	35.8219	11.7882	-0.4965	1.6495
ION GEOPHYSICAL	-1.2835	-89.6188	59.9957	21.1063	-0.8646	3.1337
KEY ENERGY SVS.	-1.2911	-65.2984	59.2927	18.4426	-0.5735	1.5290
NABORS INDUSTRIES	-0.3236	-48.0354	46.4501	13.6100	-0.3710	2.0900
NOBLE CORPORATION	-0.1349	-37.9339	33.8004	11.7220	-0.4949	1.2420
NOV	0.7721	-46.0240	30.8467	12.6183	-0.5837	1.1796
OCEANEERING	1.1791	-55.4707	28.2350	12.2513	-0.9154	3.0111
ROWAN COMPANIES CL.A	-0.1262	-45.7890	34.0682	12.0091	-0.2273	0.9514
RPC	1.5101	-50.3657	54.0230	14.7316	-0.2564	1.1482
SCHLUMBERGER	0.4044	-43.5807	23.5694	9.9437	-0.7066	1.9142
TIDEWATER	-0.7973	-35.6623	34.1640	11.1461	-0.4077	0.4735
WEATHERFORD INTL.	0.1818	-49.3135	39.4692	13.1864	-0.5229	1.8778
Oil Equipment & Services Average	0.0930	-50.6027	37.9141	13.2277	-0.5984	1.8472
Pipelines						
ENBRIDGE ENERGY PTNS.LP	0.0263	-36.3787	22.2992	6.9217	-0.5970	4.3403
OGE ENERGY	0.3950	-18.6476	19.4187	5.9177	-0.3279	1.2849
PLAINS ALL AMER.PIPE.LP. UNIT	0.5468	-24.2998	14.9783	5.9473	-0.8198	2.4953
TC PIPELINES	0.4904	-25.5187	20.3261	6.0174	-0.2160	2.0593
WILLIAMS	0.0967	-66.1419	39.3496	13.6781	-1.1183	4.4103
Pipelines Average	0.3180	-31.7871	22.9538	7.3668	-0.5411	2.6897
Royalty Trusts						
BP PRUDEHOE BAY RTY. TST.	0.5338	-30.8359	22.5505	9.2939	-0.4388	0.2660
CROSS TIMBERS RTY.UNT.	0.0971	-83.1237	24.2189	11.5923	-2.4860	15.3475

Company Name	Mean (%)	Min. (%)	Max. (%)	St. Dev. (%)	Skewness	Kurtosis
DOM.RES.BLK.WARRIOR UTS.	-1.7521	-87.9511	45.9354	14.4123	-2.0818	11.6544
HUGOTON ROYALTY TST.	-0.7629	-71.5321	27.0357	11.4639	-1.4362	7.1627
PERMIAN BASIN RTY.TST.	-0.0719	-35.1353	28.3770	8.5284	-0.3573	1.5554
SABINE ROYALTY TST.	0.3259	-35.7536	26.5223	8.6961	-0.7334	2.0447
SAN JUAN BASIN RTY.TST.	-0.4524	-51.5348	20.1890	10.0475	-1.2095	3.8487
Royalty Trusts Average	-0.4360	-60.8385	28.7131	10.7901	-1.3840	6.9356

Table 3 presents descriptive statistics for the independent variables. We see that the market, oil and interest rate factors have negative skewness. The means of the factors are positive, except for gas price and interest rate. The interest rate and the Fama-French factors have excess kurtosis over 3.

Table 3: Descriptive Statistics for the Risk Factors

	Mean	Min.	Max.	St. Dev.	Skewness	Kurtosis
Market	0.0513 %	-18.3914 %	14.6016 %	4.8946 %	-0.7212	1.8251
Oil price	0.2573 %	-43.2885 %	25.3943 %	9.8051 %	-0.7029	1.5557
Gas price	-0.0344 %	-47.4530 %	63.1899 %	15.1649 %	0.3175	1.5417
Interest rate	-0.5398 %	-35.1589 %	29.1473 %	6.1879 %	-0.5376	9.8959
Size	0.2933 %	-16.7000 %	22.3200 %	3.4831 %	1.0136	10.9652
B/M	0.3645 %	-13.1100 %	13.9100 %	3.2930 %	0.1494	3.8555
VIX	2.9646	2.3331	4.2269	0.3570	0.6445	0.2921

We have conducted a correlation analysis of the seven risk factors prior to running our regressions. Table 4 presents the results of this analysis. Some of the risk factors are correlated but none have values over 0.3496. Therefore, we are not worried about multicollinearity. The highest correlation is between the crude and market factor.

Table 4: Correlation Matrix between the Risk Factors

$R_{mt} - R_{ft}$ is the excess return on the S&P 500 market index less the risk-free interest rate, $R_{Oil,t}$ and $R_{Gas,t}$ are the logarithmic return of the WTI oil price and the NYMEX natural gas price, $R_{Int,t}$ stands for the logarithmic change in 10 year U.S. Treasury Bond yield, SMB_t is the relative performance of small stocks compared to big stocks, HML_t is the relative difference of value stocks compared to growth stocks, $Ln_{VIX,t}$ is the ln transformed SPX volatility index.

	Market $R_{mt} - R_{ft}$	Oil price $R_{Oil,t}$	Gas price $R_{Gas,t}$	Interest rate $R_{Int,t}$	Size SMB_t	B/M HML_t	VIX $Ln_{VIX,t}$
Market	1						
Oil price	0.3496	1					
Gas price	0.0374	0.2829	1				
Interest rate	0.2590	0.1746	0.0210	1			
Size	0.0551	0.0360	-0.0264	0.0297	1		
B/M	0.1508	0.1634	-0.0775	-0.0192	-0.3382	1	
VIX	0.0103	-0.0266	-0.0415	-0.1662	0.1029	-0.0691	1

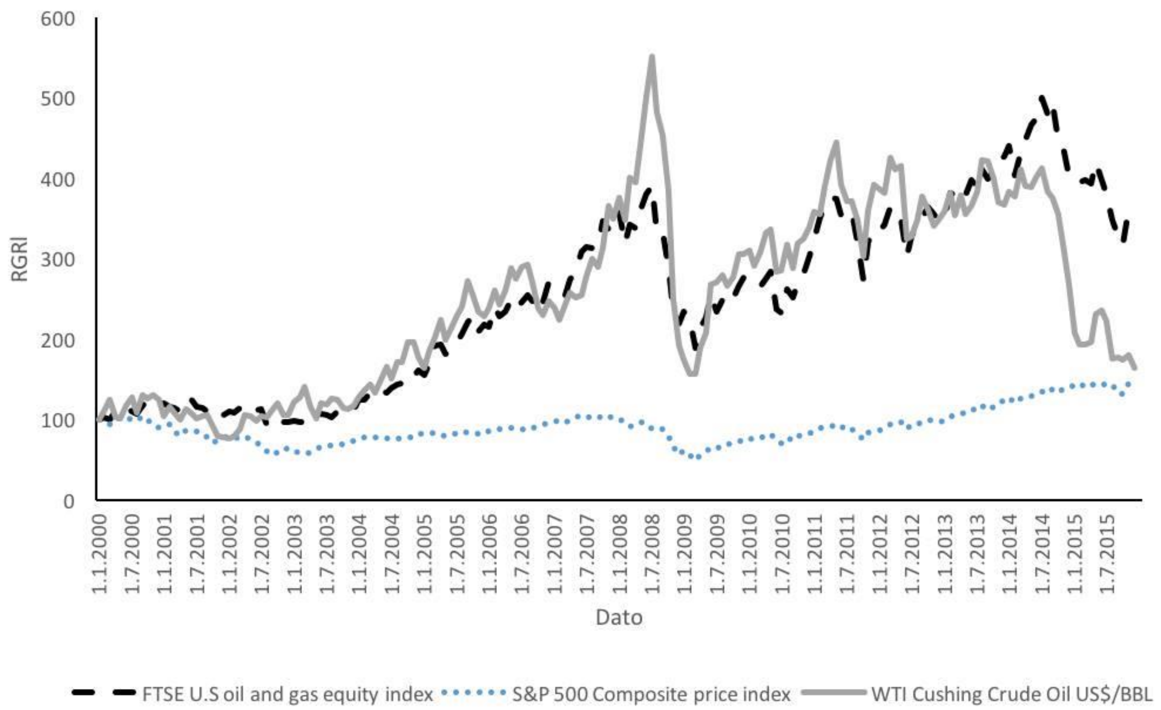

Figure 1 : Relative growth of the FTSE U.S. oil and gas industry index, the S&P 500 index and the WTI oil price.

5. Empirical Results

Figure 1 shows the relative growth of the crude price, the S&P 500 index and the FTSE U.S. oil and gas industry index, from January 2000 to December 2015. As the figure shows, the oil price had a period of substantial growth from May 2003 to July 2008. The oil and gas industry followed the oil price in this period, while the market in general had a varying relationship with the oil price. In 2014 the crude price falls and hereafter, the oil and gas sector does not seem to follow it as closely as before. Here we also see that the market is rising when the oil price is falling, implying a nonlinear relationship between the variables.

We have used the data and method presented to run a Markov switching regression. The model is applied on both the subsector level and firm level. The following section presents the results of our regression.

5.1 Subsector Level

To further examine the effect of oil and gas industry characteristics, we have performed a Markov switching regression on portfolios representing the five subsectors and the U.S. oil and gas sector as a whole. The six portfolios are equally weighted and include the stocks in our sample, sorted by subsector. Table 5 and table 6 present the results of our regression on the subsector level[7].

[7] We have conducted a robustness test, where we have split our sample in different time periods, according to the probabilities of being in a given regime. We then ran a linear regression on these time periods. The test confirmed the magnitude and significance of the parameters reported in table 5 and 6.

Table 5: Risk Factor Sensitivities of U.S. Oil and Gas Firms in the High Volatility Regime: Subsector Level

Risk sensitivities of the five U.S. oil and gas subsectors and the U.S. oil and gas sector in the high volatility regime: Exploration and production, integrated oil and gas, oil equipment and services, pipelines, Royalty Trusts and the U.S. oil and gas sector as a whole. Our regression model is: $R_{it} - R_{ft} = \alpha_{st} + \beta_{1,i,st}(R_{mt} - R_{ft}) + \beta_{2,i,st}R_{Oil,t} + \beta_{3,i,st}R_{Gas,t} + \beta_{4,i,st}R_{Int,t} + \beta_{5,i,st}SMB_t + \beta_{6,i,st}HML_t + \beta_{7,i,st}Ln_{VIX,t} + \varepsilon_{i,st}$

Subsector	Intercept α_{st}	Market $\beta_{1,i,st}$	Oil price $\beta_{2,i,st}$	Gas price $\beta_{3,i,st}$	Interest rate $\beta_{4,i,st}$	Size $\beta_{5,i,st}$	B/M $\beta_{6,i,st}$	VIX $\beta_{7,i,st}$
Exploration and production	-0.1140	0.8697***	0.4056***	0.2990***	0.1400	-0.1406	-0.3743	0.0391
	(-1.05)	(4.01)	(3.39)	(3.21)	(0.54)	(-0.47)	(-1.18)	(1.14)
Integrated oil and gas	0.0810	0.8014***	0.1799*	0.0944*	-0.1745	0.0239	-0.2903	-0.0199
	(0.61)	(5.04)	(1.91)	(1.67)	(-0.87)	(0.13)	(-1.18)	(-0.50)
Oil equipment and services	-0.0229	1.2237***	0.4631***	0.0457	0.0188	-0.2719	-0.1100	0.0059
	(-0.63)	(12.38)	(9.09)	(1.51)	(0.27)	(-1.88)	(-0.75)	(0.48)
Pipelines	-0.0643**	0.4074***	0.1332***	0.0186	0.0698	0.0735	-0.0995	0.0266***
	(-2.30)	(5.42)	(3.97)	(0.95)	(1.50)	(0,81)	(-1.00)	(2.86)
Royalty Trusts	-0.1858	0.2750	0.3438**	0.1310	0.8699**	-0.1468	-0.0607	0.0466
	(-1.34)	(0.75)	(2.00)	(1.08)	(2.17)	(-0.20)	(-0.10)	(1.05)
U.S. oil and gas sector	-0.0961	0.8050***	0.3566***	0.2228***	0.1238	-0.0718	-0.2499	0.0326
	(-1.10)	(4.64)	(3.73)	(3.00)	(0.58)	(-0.30)	(-0.98)	(1.19)

Where *,**,*** denotes significance on 10%, 5% and 1% level.

Table 6: Risk Factor Sensitivities of U.S. Oil and Gas Firms in the Low Volatility Regime: Subsector Level

Risk sensitivities of the five U.S. oil and gas subsectors and the U.S. oil and gas sector in the low volatility regime: Exploration and production, integrated oil and gas, oil equipment and services, pipelines, Royalty Trusts and the U.S. oil and gas sector as a whole. Our regression model is: $R_{it} - R_{ft} = \alpha_{st} + \beta_{1,i,st}(R_{mt} - R_{ft}) + \beta_{2,i,st}R_{Oil,t} + \beta_{3,i,st}R_{Gas,t} + \beta_{4,i,st}R_{Int,t} + \beta_{5,i,st}SMB_t + \beta_{6,i,st}HML_t + \beta_{7,i,st}Ln_{VIX,t} + \varepsilon_{i,st}$

Subsector	Intercept α_{st}	Market $\beta_{1,i,st}$	Oil price $\beta_{2,i,st}$	Gas price $\beta_{3,i,st}$	Interest rate $\beta_{4,i,st}$	Size $\beta_{5,i,st}$	B/M $\beta_{6,i,st}$	VIX $\beta_{7,i,st}$
Exploration and production	0.0273	1.1149***	0.4129***	0.0944***	-0.0039	-0.3822**	0.2041	-0.0090
	(0.78)	(9.82)	(7.91)	(3.71)	(-0.06)	(-2.29)	(1.02)	(-0.74)
Integrated oil and gas	0.0438	0.9593***	0.3740***	0.0100	-0.0140	-0.2629*	-0.0516	-0.0161
	(1.49)	(10.06)	(7.10)	(0.44)	(-0.29)	(-1.80)	(-0.29)	(-1.54)
Oil equipment and services	-0.0219	0.7672***	-0.0747***	0.3065***	-1.3118***	0.4202***	-0.1131**	0.0202***
	(-1.20)	(27.14)	(-5.89)	(38.30)	(-21.32)	(13.00)	(-2.57)	(3.38)
Pipelines	0.1100**	1.1197***	0.2011***	-0.0010	-0.5065***	-0.6264**	0.4252	-0.0486***
	(2.00)	(7.98)	(2.90)	(-0.02)	(-3.71)	(-2.48)	(1.60)	(-2.65)
Royalty Trusts	-0.0491	0.2062**	0.2640***	0.1552***	-0.0514	0.0453	0.1163	0,0184
	(-1.39)	(2.09)	(5.66)	(5.41)	(-0.80)	(0.39)	(0.85)	(1.53)
U.S. oil and gas sector	0.0146	1.0422***	0.3674***	0.0698***	-0.0053	-0.2840**	0.1725	-0,0051
	(0.52)	(11.74)	(8.71)	(3.38)	(-0.11)	(-2.13)	(1.07)	(-0.52)

Where *,**,*** denotes significance on 10%, 5% and 1% level.

The market factor is significant for all the subsectors and regimes, except for Royalty Trusts in the high volatility regime. Pipeline is the subsector with the highest market sensitivity in the low volatility regime, with a beta of 1.1197. In the high volatility regime, oil equipment and services has the highest sensitivity towards the market factor, with a beta of 1.2236. The market factor has the highest impact on returns for all subsectors, except Royalty Trusts. This implies that the market sentiment has been the most important driver of returns in the U.S. oil and gas sector in our sample period. This supports the findings of Mohanty and Nandha (2011) for the U.S. oil and gas industry. The same results are also found in studies of other markets[8]. The magnitude of the market betas varies between regimes for all subsectors. Pipelines vary from 1.1197 in the low regime, to 0.4075 in the high volatility regime. For Royalty Trusts the market beta is significant only in the low volatility regime, with a beta of 0.2062. This indicates that Royalty Trusts have the least market risk exposure in the U.S. oil and gas industry. The different exposures towards the market factor in different regimes have implications for both hedging decisions and for the composition of portfolios.

Oil price is a significant variable for all the subsectors in both regimes. This supports earlier studies which also report similar findings[9]. This is not surprising, due to the fact that oil is a major input/output for the sector. For the exploration and production subsector, the impact of the oil price is similar in both regimes, with the betas being 0.4055 in the high volatility regime and 0.4128 in the low volatility regime. For pipelines, the oil coefficient is also stable across regimes, but it is lower in magnitude than for exploration and production. This can be explained by this subsector's ability to pass on increased costs to their customers (Boyer and Filion 2007). Integrated oil and gas has a dampened sensitivity towards crude in the high volatility regime compared to the low volatility regime, respectively 0.1798 and 0.373981. This might be due to hedging and that some of the costs of volatility are offset in downstream activities[10]. To our surprise, oil equipment and services has a negative relation with the oil price in the low volatility regime. This coefficient is, however, small. The impact is 0.4631 in the high volatility regime, and -0.0747 in the low volatility regime.

[8] Ramos and Veiga (2011) find the same for developed markets and emerging markets. Sadorsky (2001) for Canada, El-Shariff et al. for the UK and Tjaaland et al. (2015) for the U.S.
[9] E.g. Mohanty and Nanda (2011) and Tjaaland et al. (2015) for the U.S., Sadorsky (2001) and Boyer and Fillion (2007) for Canada, El-Sharif et al. (2005) for the UK and Ramos and Veiga (2011) for developed and emerging markets.
[10] Refining and marketing activities.

Natural gas is significant for three out of five subsectors in the low volatility regime. Exploration and production has significant exposure in the high volatility state. Integrated oil and gas also has significant exposure to natural gas in the high volatility regime, but only at the 10 percent level. The impact of the gas factor on the exploration subsector is highest with a beta of 0.2989 in the high volatility regime. In the low volatility regime this impact is dampened to 0.0944. In this regime, natural gas also has a positive and significant impact on Royalty Trusts and the equipment and services sector. These sectors do not have significant exposures in the high volatility regime. Overall, we see that the oil price has a greater impact on returns than the price of natural gas.

VIX is significant for pipelines in both regimes and significant for equipment in the low regime. The coefficients are small and positive except for pipeline in the low volatility regime, where it is small and negative. These two sectors shift most frequently between regimes, which indicates that they are more sensitive towards the market volatility. Surprisingly, the interest rate factor is significant and positive for Royalty Trusts in the high volatility regime. This might be due to the fact that they own oil fields and employ external drillings companies. This could in turn reduce some of the operational risk associated with exploration and production activities. In the low volatility regime, the interest rate factor is significant and negative for pipelines, with a beta of -0.5064 and the equipment and services sector with a beta of -1.3117. This is in line with our a priori hypothesis, that an increase in borrowing costs decreases profits. The firms in the other three subsectors own oil reserves, which creditors might consider as better collateral than engineers and pipelines.

The Fama-French factors, HML and SMB, are not significant for the five subsectors in the high volatility regime. For the low volatility regime, SMB is significant and negative for exploration, integrated and pipelines. Equipment has a significant and positive exposure to the SMB factor in the low volatility regime, with a beta of 0.4202. Pipeline has the lowest SMB beta of -0.6264. HML is only significant for equipment and services in the low regime with a beta of -0.1131. These findings differ from Mohanty and Nandha (2011), who find HML to be more significant in explaining the returns, compared to SMB. This might be due to our sample period being different from theirs. The results indicate that the premium for holding smaller companies only has an effect on the subsectors in the low volatility regime. This supports the theory that in times of market distress, it is desirable to hold companies with higher value assets on the books.

Figure A1 shows the probabilities of being in either the high or the low volatility regime. The regimes seem to follow the business cycle from 2000 to 2014 for all subsectors. In recent years the industry has entered a high volatility regime, which is most likely caused by the volatility in the oil price. Interestingly, the integrated oil and gas subsector does not seem to enter a high volatility regime in 2014. This supports our earlier findings and shows that integrated companies can partly offset decreased earnings in the downstream activities with decreased costs in the upstream operations[11]. The pipeline subsector has the most shifts between regimes of all the subsectors. Table A4 presents the expected durations of the two regimes for the subsectors. Integrated oil and gas has the longest expected duration in the low volatility regime, 64.3369 months. Exploration and production and Royalty Trusts are quite similar in the duration of the low volatility regime of 45.326 and 43.4875 months. The shorter expected regime durations for these subsectors in the low volatility regime compared to the integrated oil and gas subsector is due to the latter not entering the high volatility state in 2014. This is when they entered a high volatility regime, while integrated oil and gas remained in the low volatility state. Royalty Trusts have a shorter expected duration in the high volatility regime compared to exploration and production, with 11.3842 months versus 31.7197 months.

Our results show asymmetries both over time and across subsectors. The market factor is greatest in size for oil equipment and services in the high volatility regime, but it has only the second lowest exposure in the low volatility regime. The pipeline subsector has the highest exposure towards the market in the low volatility regime. This shows that coefficients also vary in size across regimes, indicating asymmetrical risk exposure in different market regimes. Overall, the market factor has the highest impact on returns in the subsectors, except Royalty Trusts.

The exploration and production subsector has a significant exposure to both crude oil and natural gas prices in both regimes. The oil price sensitivities of the integrated subsector have a dampened effect in the high volatility regime compared to the low, while the exploration and production subsector has a stable exposure to crude across both regimes. The oil beta is highest with 0.4631 for equipment and services in the high volatility regime, and lowest for the same subsector in the low volatility regime with -0.0747. We find that the price of oil has

[11] Exploration and production activities.

a higher impact on returns than the natural gas factor. The probability of being in different regimes seems to follow the business cycle, but in 2014 the subsectors, except integrated oil and gas, seem to follow the decline in oil price. Furthermore, the intercepts are insignificant, except for the pipeline sector which has significant intercepts in both regimes. This shows that our model helps explain much of the variance in the returns of the U.S. oil and gas sector.

5.2 Firm Level

The regression results of the 66 firms and Royalty Trusts are presented in table A2 and table A3 in the appendix. Our two regimes display different numbers of significant variables. The low volatility regime has more significant variables than the high volatility regime. Out of the 66 intercepts, 11 and 25 are statistically significant in the high and low volatility regime. This shows that our model helps explain much of the variance in the excess return of U.S. oil and gas companies.

The market factor in the high and low volatility regime is significant in 53 and 59 cases. Swift has the highest market coefficient in the high volatility regime with a beta of 3.3993. In the low volatility regime Superior has the highest market beta of 5.0316 and Clayton Williams Energy has the lowest market beta of -1.1115, both are in the exploration and production subsector. This makes Swift and Superior the most volatile stocks in our sample. Royalty Trust has the lowest market beta in both the high and low volatility regime. The firms in this subsector has the least market risk exposure in the sample period, regardless of regime. We get a market beta of 0.9130 and 0.8578, when averaging the market beta for all the 66 firms in the high and low volatility regime. This implies that the firms in our sample have been less risky than the market in the sample period for both regimes.

The market factor has a greater influence on returns in the high volatility regime, compared to the low volatility regime, for both exploration and production and pipeline firms, e.g. Anadarko and TC Pipelines. A possible reason for this is the change in covariance in economic downturns, and investors' nervousness. Oil equipment and services have the highest exposure towards the market factor and are stable across regimes. This implies that the market factor is an important risk factor for oil equipment firms, regardless of regime, e.g. Noble Corporation. Within the same subsector, Ensco has market coefficients of 0.9050 and 4.8950 in the high and low volatility regime. For integrated oil and gas firms the market factor has a bigger impact in the low volatility regime.

The oil price factor is significant for 48 and 58 firms in the high and low volatility regime. Dominon Resources Black Warrior Royalty Trust has the highest exposure towards the oil factor, with a coefficient of 2.2855 in the high volatility regime. Clayton Williams, in the exploration and production subsector, has the highest exposure towards the oil factor in the low volatility regime with a coefficient of 2.0819. Hess' sensitivity towards the crude factor has a bigger impact in the low volatility regime, which reflects most integrated oil and gas firm's sensitivities towards this risk factor. While Suncor Energy, within the same subsector, has coefficients of 1.0323 and 0.4290 in the high and low volatility regime. This shows that there are differences across firms in the same subsector.

Regarding Royalty Trusts, we notice that oil price is of higher importance in the high volatility regime. In the low volatility state, the focus seems to shift to the market. Oil price has a bigger impact on returns in the high volatility regime than in the low volatility regime for firms in oil equipment and services. Crude has a bigger impact on oil producing companies (exploration and production and Royalty Trusts), with higher coefficients than the other subsectors. We find evidence that the oil price has a significant impact on returns. This supports previous research, e.g. Mohanty and Nandha (2011), Boyer and Filion (2007) and Sadorsky (2001).

Concerning the natural gas factor, the number of significant variables is 27 and 42 for the high and low volatility regime, which is less than for the oil price factor. We also see that the companies' returns have lower sensitivities towards the gas factor, compared to the oil price factor. A possible reason for this is that energy firms are more likely to hedge the exposure towards natural gas price volatility than hedging the oil price volatility (Boyer and Filion, 2007). Natural gas price has a bigger impact in the high volatility regime for the firms in the exploration and production, integrated oil and gas and Royalty Trusts, however, there are exceptions. In addition, the gas price sensitivity is of marginal difference for the two regimes for oil equipment and services firms. The effect of the natural gas price on returns is dampened for integrated oil and gas firms. This might be due to firms in this subsector having a natural hedge through the use of oil and gas as an input in downstream operations (Tjaaland et al. 2015). For the pipeline subsector, there are few significant gas coefficients in the high volatility regime; however, Enbridge has a negative statistical significant gas factor in the high volatility regime, being the only firm in our sample this applies to.

Interest rate is found to be a significant variable for 15 and 26 firms in the high and low volatility regime. This factor varies between -1.6748 and 4.3432 in the high volatility regime, and between -3.4143 and 3.7928 in the low volatility regime. Both SMB and HML tend to be more significant in the low volatility regime. The SMB coefficients in the high volatility regime have a negative mean in three out of five subsectors (exploration and production, pipelines and Royalty Trusts). The means for these subsectors become less negative in the low volatility regime. This might imply that one is more concerned whether or not smaller firms are able to avoid default in economic downturns. VIX is found to be significant in 15 and 27 cases in the high and low volatility regime. Chesakape has the highest exposure in the high volatility regime towards the VIX factor, with a beta of 0.2609. Clayton Williams has the highest VIX exposure in the low volatility regime with a beta of 0.1336. Both Chesakape and Clayton Williams are in the exploration and production subsector.

The expected durations for all firms are presented in table A5 in the appendix. Anadarko's high and low volatility regimes are expected to last for 8.2 and 27.6 months. Hess is expected to be in the high or the low volatility regime for approximately 20.6 and 33.7 months. Enbridge's high and low volatility regimes are expected to last for approximately 7.2 and 114.6 months. The high and low volatility regimes are expected to last 13.1 and 28.5 months for Noble Corporation. For Hugoton the high and low volatility regimes are expected to last for 7.2 and 44 months. When averaging the duration for all firms and Royalty Trusts we find that the high volatility regime is expected to last for 16.4 months and the low volatility regime expected to last for 12.9 months. This illustrates that there are differences in expected durations, both across firms and regimes.

Figure A2 in the appendix shows graphs illustrating the smoothed regime probabilities for each of the 66 firms and Royalty Trusts. The probability *P(s(t)=1)* is the probability of a firm being in the high volatility state at time *t*. The probability *1-P(s(t))* denotes the probability of a firm being in the low volatility regime at time *t*. For exploration and production and Royalty Trusts the transition probability graphs seem to follow the business cycle until 2014, when their graphs show high probability of being in the high volatility state. This coincides with the recent decline in oil prices, e.g. Anadarko. Integrated oil and gas firms do not seem to follow this trend, which confirms our subsector results. Chevron's regime probability graph illustrates this, with high probabilities of being in the high volatility regime in 2000 and 2008 when the .com bubble and the financial crisis hit. We see that there is more noise in the regime probability graphs at the firm level compared to subsector level. This might be due to noise in the time series or that the distributions for the high and low volatility regimes are similar.

We find that the oil equipment and services subsector have the highest exposure towards the market factor, which supports our findings on subsector level for the high volatility regime. Royalty Trusts have the lowest exposure towards the market factor, for both regimes. For exploration and production and pipelines, the market factor is of higher importance in the high volatility regime. Overall, we find that the oil price has a positive and significant impact on returns of U.S. oil and gas companies. We also find that crude has a bigger impact on the returns of firms in exploration and production and Royalty Trusts in the high volatility regime, compared to other subsectors. For integrated oil and gas companies, the crude factor has a bigger impact in the low volatility regime compared to the high volatility regime. This supports our subsector findings.

For most firms, the oil price factor has greater influence on returns than the natural gas factor, which also applies to the subsector level. Interest rate and VIX are found to be significant for only a few of the firms. For the risk factor sensitivities, we find differences across firms, both within and between subsectors, as well as across regimes. For all subsectors, except integrated oil and gas firms, the regime probabilities seem to follow the business cycle until 2014, when the decrease in oil prices caused the subsectors to enter a high volatility state.

6. Conclusion

We use a Markov switching regression to investigate the relationship between the excess return of firms in the U.S. oil and gas industry and seven risk factors. We use monthly data for 66 oil and gas companies, all listed on the NYSE, in the period January 2000 to December 2015. We augment Fama and French’s (1992) three-factor asset pricing model, with crude oil and natural gas prices, an interest rate factor and a volatility factor. To our knowledge, this is the first study that uses a Markov switching regression to estimate the coefficients of the risk factors mentioned above on a sample of U.S. oil and gas companies, on both the firm and subsector level. In addition, the Fama-French factors have to our knowledge, not previously been used on a sample that includes Royalty Trusts.

In accordance with our a priori expectations, we find the market factor and the price of crude oil to be positive and significant risk factors in explaining returns in the U.S. oil and gas industry, both on the firm and subsector level. We find that, in the high volatility regime, equity returns of oil equipment and services have the highest exposure towards the market factor. In the low volatility regime the same subsector has the second lowest exposure. This implies asymmetry across regimes. Compared to the other risk factors, the market factor has the highest impact on returns, except for Royalty Trusts. This shows that the market factor has been the most important driver of returns in the U.S. oil and gas industry in our sample period.

We find that the oil price has a stronger impact in the high volatility regime for Royalty Trusts and oil equipment and services, compared to the low volatility regime. For exploration and production we find the oil price sensitivity to be stable across regimes. Integrated oil and gas has a dampened effect towards the oil price in the high volatility regime, compared to the low volatility regime. The crude price factor has a greater impact on excess return of oil producing companies (exploration and production and Royalty Trusts), compared to the other subsectors. We find that the oil price has a greater influence on returns than the price of natural gas. Overall, we find oil price to be a positive and significant risk factor for most firms and subsectors.

The probability of returns being in the high or low volatility regime coincides, in most cases, with the business cycle. However, in recent years, the returns of oil producing companies seem to follow the decline in oil prices. Interestingly, returns of integrated oil and gas companies do not seem to enter the high volatility regime with the recent decline in oil prices. This shows an asymmetric relationship between the business cycle and returns of the oil and gas companies in our sample. We also find that the significance and size of the sensitivities vary across firms, subsectors and regimes. This indicates that returns for taking risks vary between economic regimes, and that the subsectors and firms are non-homogenous.

Our results have importance for both hedging decisions and capital allocation. The evidence presented of varying oil price risk between regimes, subsector and firms should be of interest for decision makers in the industry and both private and institutional investors. We also further contribute to the literature with evidence of asymmetric risk factor sensitivities. Our study shows that the application of a Markov switching regression on stock returns is promising in explaining asymmetric risk sensitivities. To further extend our research, we suggest application of the method on other sectors and markets. It would also be interesting to apply the method on other risk factors.

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Appendix

Table A 1: List of the U.S. Oil and Gas Companies Included in Our Sample

Company Name	Subsector	Ticker
ANADARKO PETROLEUM	Exploration & Production	APC
APACHE	Exploration & Production	APA
ATWOOD OCEANICS	Exploration & Production	ATW
CABOT OIL & GAS 'A'	Exploration & Production	COG
CALLON PTL.DEL.	Exploration & Production	CPE
CHESAPEAKE ENERGY	Exploration & Production	CHK
CLAYTON WILLIAMS EN.	Exploration & Production	CWEI
COMSTOCK RES.	Exploration & Production	CRK
DENBURY RES.	Exploration & Production	DNR
DEVON ENERGY	Exploration & Production	DVN
DIAMOND OFFS.DRL.	Exploration & Production	DO
ENERGEN	Exploration & Production	EGN
EOG RES.	Exploration & Production	EOG
EQT	Exploration & Production	EQT
GOODRICH PTL.	Exploration & Production	GDP
MARATHON OIL	Exploration & Production	MRO
NEWFIELD EXPLORATION	Exploration & Production	NFX
NOBLE ENERGY	Exploration & Production	NBL
OCCIDENTAL PTL.	Exploration & Production	OXY
PANHANDLE OIL & GAS	Exploration & Production	PHX
PARKER DRILLING	Exploration & Production	PKD
PETROQUEST ENERGY	Exploration & Production	PQ
PIONEER NTRL.RES.	Exploration & Production	PXD
RANGE RES.	Exploration & Production	RRC
SM ENERGY	Exploration & Production	SM
STONE ENERGY	Exploration & Production	SGY
SUPERIOR ENERGY SVS.	Exploration & Production	SPN
SWIFT ENERGY	Exploration & Production	SFY
TRANSOCEAN	Exploration & Production	RIG
UNIT	Exploration & Production	UNT
VAALCO ENERGY	Exploration & Production	EGY
CHEVRON	Integrated Oil & Gas	CVX
CONOCOPHILLIPS	Integrated Oil & Gas	COP
ENI SPA SPN.ADR 1:2	Integrated Oil & Gas	E
EXXON MOBIL	Integrated Oil & Gas	XOM
HESS	Integrated Oil & Gas	HES
MURPHY OIL	Integrated Oil & Gas	MUR
SUNCOR ENERGY INCO.	Integrated Oil & Gas	SU
BAKER HUGHES	Oil Equipment & Services	BHI

Company Name	Subsector	Ticker
BUCKEYE PARTNERS	Oil Equipment & Services	BPL
ENSCO CLASS A	Oil Equipment & Services	ESV
HALLIBURTON	Oil Equipment & Services	HAL
HELMERICH & PAYNE	Oil Equipment & Services	HP
ION GEOPHYSICAL	Oil Equipment & Services	IO
KEY ENERGY SVS.	Oil Equipment & Services	KEG
NABORS INDUSTRIES	Oil Equipment & Services	NBR
NOBLE CORPORATION	Oil Equipment & Services	NE
NATIONAL OILWELL VARCO	Oil Equipment & Services	NOV
OCEANEERING	Oil Equipment & Services	OII
ROWAN COMPANIES CL.A	Oil Equipment & Services	RDC
RPC	Oil Equipment & Services	RES
SCHLUMBERGER	Oil Equipment & Services	SLB
TIDEWATER	Oil Equipment & Services	TDW
WEATHERFORD INTL.	Oil Equipment & Services	WFT
ENBRIDGE ENERGY PTNS.LP	Pipelines	EEP
OGE ENERGY	Pipelines	OGE
PLAINS ALL AMER.PIPE.LP. UNIT	Pipelines	PAA
TC PIPELINES	Pipelines	TCP
WILLIAMS	Pipelines	WMB
BP PRUDEHOE BAY RTY. TST.	Exploration & Production	BPT
CROSS TIMBERS RTY. UNT.	Exploration & Production	CRT
DOM.RES.BLK.WARRIOR UTS.	Exploration & Production	DOM
HUGOTON ROYALTY TST.	Exploration & Production	HGT
PERMIAN BASIN RTY.TST.	Exploration & Production	PBT
SABINE ROYALTY TST.	Exploration & Production	SBR
SAN JUAN BASIN RTY.TST.	Exploration & Production	SJT

Table A 2 Risk Factor Sensitivities of U.S. Oil and Gas Firms in the High Volatility Regime: Firm Level

Risk sensitivities, in the high volatility regime of the U.S. oil and gas firms in our sample, for the following subsectors: Exploration and Production, Integrated Oil and Gas, Oil Equipment and Service, Pipelines and Royalty Trusts. Our regression model is as follows:

$R_{it} - R_{ft} = \alpha_{st} + \beta_{1,i,st}(R_{mt} - R_{ft}) + \beta_{2,i,st}R_{Oil,t} + \beta_{3,i,st}R_{Gas,t} + \beta_{4,i,st}R_{Int,t} + \beta_{5,i,st}SMB_t + \beta_{6,i,st}HML_t + \beta_{7,i,st}Ln_{VIX,t} + \varepsilon_{i,st}$

Company name	Intercept α_{st}	Market $\beta_{1,i,st}$	Oil price $\beta_{2,i,st}$	Gas price $\beta_{3,i,st}$	Interest rate $\beta_{4,i,st}$	Size $\beta_{5,i,st}$	B/M $\beta_{6,i,st}$	VIX $\beta_{7,i,st}$
Exploration & Production								
ANADARKO PETROLEUM	-0.2457	1.2055**	0.1764	0.2010	-1.0611	0.1575	-0.1164	0.0797
	(-0.88)	(2.18)	(0.72)	(1.21)	(-0.94)	(0.28)	(-0.17)	(0.89)
APACHE	-0.0511	2.0296***	-0.2585*	0.4344***	0.1440	-0.4670	-0.7387**	0.0178
	(-0.34)	(7.87)	(-1.69)	(4.42)	(0.97)	(-1.26)	(-1.87)	(0.39)
ATWOOD OCEANICS	0.0616	1.1869***	0.5862***	0.0194	-0.0307	-0.4954**	-0.4011*	-0.0240
	(1.16)	(7.89)	(7.42)	(0.40)	(-0.29)	(-2.10)	(-1.74)	(-1.33)
CABOT OIL & GAS 'A'	-0.0665	1.0746***	0.2222*	0.3924***	0.1258	-0.3728	-1.0338***	0.0285
	(-0.71)	(4.02)	(1.73)	(5.12)	(0.63)	(-1.04)	(-2.77)	(0.91)
CALLON PTL.DEL.	0.5234	2.5888***	0.5602	0.0902	0.5177	-0.7076	-1.2195	-0.1719
	(1.58)	(3.86)	(1.43)	(0.38)	(0.97)	(-0.64)	(-1.00)	(-1.64)
CHESAPEAKE ENERGY	-0.7928***	0.5554	0.5254**	0.7008***	-1.6748**	-0.2134	-0.5722	0.2609***
	(-2.78)	(1.11)	(2.27)	(4.65)	(-2.39)	(-0.41)	(-0.96)	(2.81)
CLAYTON WILLIAMS EN.	0.0017	1.8377***	0.0239	0.2804***	-0.0319	-0.4551	-0.5931	-0.0013
	(0.02)	(6.88)	(0.17)	(3.27)	(-0.17)	(-1.25)	(-1.56)	(-0.04)
COMSTOCK RES.	-0.2848	-1.2612	1.3428***	0.3040	0.7857	-0.0956	-1.2718	0.0896
	(-0.72)	(-1.38)	(2.91)	(0.83)	(1.22)	(-0.09)	(-1.10)	(0.69)
DENBURY RES.	-0.0142	1.1160***	0.5584***	0.0542	-0.2949	0.0088	-0.4940	0.0054
	(-0.12)	(3.75)	(3.51)	(0.55)	(-1.04)	(0.02)	(-1.09)	(0.14)
DEVON ENERGY	0.0064	1.7609***	-0.1100	0.3257***	0.2329**	-1.3578***	-1.0488***	-0.0026
	(0.10)	(10.70)	(-1.29)	(5.58)	(2.22)	(-4.70)	(-4.12)	(-0.12)
DIAMOND OFFS.DRL.	0.0529	0.7759***	0.2167**	0.0572	-0.0369	-0.2473	0.0714	-0.0158
	(0.84)	(4.48)	(2.38)	(1.07)	(-0.29)	(-1.02)	(0.27)	(-0.75)

Company name	Intercept α_{st}	Market $\beta_{1,i,st}$	Oil price $\beta_{2,i,st}$	Gas price $\beta_{3,i,st}$	Interest rate $\beta_{4,i,st}$	Size $\beta_{5,i,st}$	B/M $\beta_{6,i,st}$	VIX $\beta_{7,i,st}$
ENERGEN	-0.0226	0.9433***	0.3409***	0.0490	0.0096	-0.1625	-0.7365***	0.0120
	(-0.40)	(6.19)	(4.45)	(0.99)	(0.08)	(-0.79)	(-3.09)	(0.64)
EOG RES.	0.0277	1.3552***	-0.0927	0.4938***	-1.3218***	-0.1214	-0.2110	0.0034
	(0.11)	(4.11)	(-0.60)	(5.17)	(-3.43)	(-0.34)	(-0.48)	(0.04)
EQT	-0.0589	0.7558***	0.1451*	0.3035***	0.0201	-0.3359*	-0.3599*	0.0239
	(-1.02)	(5.27)	(1.84)	(5.33)	(0.19)	(-1.66)	(-1.72)	(1.25)
GOODRICH PTL.	-0.6113**	-0.8509	1.7758***	0.2064	-1.0153	1.2094	-0.3045	0.1945**
	(-2.12)	(-1.17)	(3.76)	(0.66)	(-1.41)	(1.44)	(-0.28)	(2.03)
MARATHON OIL	-0.0340	1.0561***	0.5048***	0.0280	0.0043	0.0045	-0.6326***	0.0062
	(0.48)	(0.00)	(0.00)	(0.55)	(0.96)	(0.98)	(0.00)	(0.70)
NEWFIELD EXPLORATION	-0.0365	0.9159***	0.3133***	0.0568	-0.1792*	-0.4542**	0.4786**	0.0192
	(-0.73)	(7.25)	(4.40)	(1.35)	(-1.76)	(-2.40)	(2.16)	(1.14)
NOBLE ENERGY	-0.1509**	0.9738***	-0.0387	0.1770***	-0.2515*	-0.3124	0.7235***	0.0647***
	(-2.30)	(6.69)	(-0.51)	(3.26)	(-1.88)	(-1.35)	(2.63)	(3.05)
OCCIDENTAL PTL.	-0.0222	0.7877**	-0.6356**	0.0749	-0.7453*	0.1726	-0.1874	0.0148
	(-0.14)	(2.18)	(-2.47)	(0.49)	(-1.67)	(0.53)	(-0.52)	(0.29)
PANHANDLE OIL & GAS	0.0901	0.6144***	0.3271***	0.0934	0.0671	0.0681	0.0789	-0.0262
	(1.06)	(2.64)	(2.62)	(1.31)	(0.38)	(0.21)	(0.23)	(-0.91)
PARKER DRILLING	0.1029	1.5796***	0.5231***	0.1279**	-0.0748	-0.2554	-0.5094*	-0.0405
	(1.41)	(8.18)	(5.06)	(2.19)	(-0.53)	(-0.96)	(-1.78)	(-1.64)
PETROQUEST ENERGY	0.0309	2.4330**	0.1126	0.2205	0.8225	-0.0614	-2.3215	-0.0135
	(0.12)	(2.32)	(0.32)	(1.05)	(0.96)	(-0.06)	(-1.23)	(-0.16)
PIONEER NTRL.RES.	-0.0993	1.3973***	0.5319***	0.1506**	-0.1266	-0.0757	-0.9577***	0.0356
	(-1.24)	(6.10)	(4.66)	(2.37)	(-0.66)	(-0.28)	(-2.86)	(1.32)
RANGE RES.	-0.0064	0.4411***	0.3867***	0.1411***	0.0023	-0.4268**	0.4269	0.0057
	(-0.12)	(2.96)	(5.05)	(3.11)	(0.02)	(-1.97)	(1.64)	(0.32)
SM ENERGY	-0.0290	1.4044***	0.0051	0.2388***	-0.0048	-0.5641	-0.9609***	0.0178
	(-0.37)	(5.56)	(0.03)	(3.10)	(-0.03)	(-1.18)	(-2.73)	(0.67)

Company name	Intercept α_{st}	Market $\beta_{1,i,st}$	Oil price $\beta_{2,i,st}$	Gas price $\beta_{3,i,st}$	Interest rate $\beta_{4,i,st}$	Size $\beta_{5,i,st}$	B/M $\beta_{6,i,st}$	VIX $\beta_{7,i,st}$
STONE ENERGY	-0.2798	0.3793	1.1003**	0.3573	3.2199***	-2.5474**	1.1906	0.0815
	(-0.66)	(0.68)	(2.42)	(1.18)	(3.46)	(-1.97)	(0.96)	(0.65)
SUPERIOR ENERGY SVS.	0.0517	0.8967***	0.4838***	0.0171	0.0713	-0.3602	0.0229	-0.0166
	(0.19)	(0.24)	(3.40)	(0.89)	(-0.38)	(2.17)	(-1.26)	(-0.11)
SWIFT ENERGY	0.2004	3.3993*	1.5336**	0.1828	-0.0941	-2.8056	0.0239	-0.1031
	(0.36)	(1.81)	(1.98)	(0.20)	(-0.06)	(-0.88)	(0.01)	(-0.54)
TRANSOCEAN	0.0025	1.0658***	0.3493***	0.0737	-0.2134*	-0.0799	0.2193	-0.0019
	(0.04)	(6.82)	(4.48)	(1.54)	(-1.89)	(-0.38)	(0.91)	(-0.09)
UNIT	-0.0532	0.7311***	0.5208***	0.1223***	0.2113**	-0.2485	0.3807*	0.0189
	(-1.03)	(5.23)	(7.03)	(2.79)	(2.08)	(-1.29)	(1.77)	(1.08)
VAALCO ENERGY	-0.3103	-1.7414	0.7800	-0.4953	3.2735	0.9304	-3.7318*	0.1702
	(-0.55)	(-1.38)	(1.37)	(-1.06)	(1.59)	(0.40)	(-1.83)	(0.86)
Exploration & Production Average	-0.0651	1.0131	0.4133	0.1768	0.0758	-0.3445	-0.4809	0.0236
Integrated Oil & Gas								
CHEVRON	0.0914	0.8406***	-0.1540	0.0292	-0.1653	0.3166	0.1057	-0.0272
	(0.73)	(4.60)	(-1.16)	(0.43)	(-0.70)	(1.04)	(0.34)	(-0.73)
CONOCOPHILLIPS	0.0973**	1.2168***	0.2092***	0.0301	-0.0137	-0.5174***	-0.0900	-0.0288**
	(2.26)	(7.68)	(3.71)	(0.90)	(-0.15)	(-2.87)	(-0.55)	(-2.02)
ENI SPA SPN.ADR 1:2	-0.0579	0.6669***	0.2580***	0.0711**	-0.0422	-0.2629**	-0.1177	0.0208*
	(-1.74)	(7.46)	(5.68)	(2.51)	(-0.64)	(-1.96)	(-0.88)	(1.86)
EXXON MOBIL	0.0196	0.7297***	0.1241***	0.0070	-0.0002	0.1584	-0.2475**	-0.0074
	(0.68)	(9.02)	(3.01)	(0.31)	(-0.00)	(1.54)	(-2.26)	(-0.76)
HESS	0.2220	1.0403***	0.2983**	-0.0014	-0.4083	-0.3578	-0.5850	-0.0653
	(1.24)	(4.17)	(2.21)	(-0.02)	(-1.49)	(-1.09)	(-1.59)	(-1.20)
MURPHY OIL	-0.0769	0.6986***	0.2848***	-0.0125	0.2424**	0.1507	0.2996	0.0365**
	(-1.43)	(5.23)	(4.28)	(-0.29)	(2.03)	(0.77)	(1.48)	(2.04)
SUNCOR ENERGY INCO.	0.0455	0.1393	1.0323***	0.1618	-0.2339	2.5879**	-0.8712	-0.0079
	(0.19)	(0.24)	(3.40)	(0.89)	(-0.38)	(2.17)	(-1.26)	(-0.11)

Company name	Intercept α_{st}	Market $\beta_{1,i,st}$	Oil price $\beta_{2,i,st}$	Gas price $\beta_{3,i,st}$	Interest rate $\beta_{4,i,st}$	Size $\beta_{5,i,st}$	B/M $\beta_{6,i,st}$	VIX $\beta_{7,i,st}$
Integrated Oil & Gas Average	0.048717	0.761736	0.293248	0.040758	-0.088728	0.296515	-0.215162	-0.011331
Oil Equipment & Services								
BAKER HUGHES	0.0918	1.2440***	0.5690***	0.0126	-0.0266	-0.5507**	-0.3941	-0.0369*
	(1.48)	(7.47)	(6.12)	(0.25)	(-0.17)	(-2.24)	(-1.51)	(-1.80)
BUCKEYE PARTNERS	-0.0086	0.3858***	0.0762*	0.0223	0.0104	0.1905*	0.2328*	0.0036
	(-0.25)	(4.24)	(1.73)	(0.89)	(0.17)	(1.68)	(1.81)	(0.31)
ENSCO CLASS A	-0.0462	0.9050***	0.5041***	0.0552	-0.0039	-0.5557**	0.1465	0.0139
	(-0.93)	(6.67)	(7.18)	(1.29)	(-0.04)	(-2.48)	(0.71)	(0.83)
HALLIBURTON	0.2707*	1.3189***	0.7256***	0.0669	0.0784	-0.2461	-1.2291*	-0.1098**
	(1.77)	(2.77)	(2.96)	(0.52)	(0.30)	(-0.36)	(-1.92)	(-2.13)
HELMERICH & PAYNE	-0.1653*	0.6482***	0.1516	0.1651**	0.0782	0.7293**	0.5000	0.0649**
	(-1.88)	(3.17)	(1.42)	(2.49)	(0.45)	(2.50)	(1.42)	(2.17)
ION GEOPHYSICAL	0.0393	3.2412***	0.5880**	-0.0337	-0.0505	-0.2724	-0.3406	-0.0257
	(0.19)	(6.97)	(2.34)	(-0.20)	(-0.15)	(-0.46)	(-0.44)	(-0.39)
KEY ENERGY SVS.	-0.1726	1.1294***	0.8284***	0.0986	0.1921	0.9501**	-0.1893	0.0468
	(-1.52)	(3.76)	(5.49)	(1.07)	(0.94)	(2.32)	(-0.44)	(1.24)
NABORS INDUSTRIES	-0.0930	1.2450***	0.3778***	0.2157***	0.0968	-0.3209	0.0714	0.0288
	(-1.39)	(7.03)	(4.18)	(3.95)	(0.70)	(-1.24)	(0.27)	(1.28)
NOBLE CORPORATION	-0.3174	0.9864**	0.2679	0.0547	0.0575	-0.6273	-0.9309*	0.1048
	(-1.58)	(2.46)	(1.22)	(0.38)	(0.14)	(-1.09)	(-1.68)	(1.61)
NATIONAL OILWELL VARCO	0.0236	1.1739***	0.5089***	0.1867***	-0.0840	0.4345*	-0.5292**	-0.0102
	(0.41)	(7.55)	(6.19)	(3.96)	(-0.68)	(1.91)	(-2.19)	(-0.53)
OCEANEERING	-0.2510	-0.0507	0.2076	0.2425*	0.3173	-0.3122	-0.6846	0.1078*
	(-1.48)	(-0.08)	(0.79)	(1.89)	(0.70)	(-0.65)	(-1.31)	(1.87)
ROWAN COMPANIES CL.A	-0.1030	1.2746***	0.1274	0.0784	-0.1007	0.6903*	0.2498	0.0414
	(-0.89)	(4.39)	(0.90)	(0.81)	(-0.45)	(1.67)	(0.51)	(1.07)
RPC	-0.0412	1.2792***	0.1397	0.0738	0.0529	-0.3603	0.3559	0.0178
	(-0.47)	(5.41)	(1.15)	(0.99)	(0.30)	(-0.94)	(0.95)	(0.60)

Company name	Intercept α_{st}	Market $\beta_{1,i,st}$	Oil price $\beta_{2,i,st}$	Gas price $\beta_{3,i,st}$	Interest rate $\beta_{4,i,st}$	Size $\beta_{5,i,st}$	B/M $\beta_{6,i,st}$	VIX $\beta_{7,i,st}$
SCHLUMBERGER	-0.1028	0.8187***	0.2303**	0.1585**	0.0222	0.5914**	-0.1447	0.0345
	(-1.04)	(3.99)	(2.46)	(2.16)	(0.16)	(2.02)	(-0.42)	(1.01)
TIDEWATER	-0.0125	1.1159***	0.4671***	0.0296	-0.1983	0.0333	-0.2433	-0.0018
	(-0.19)	(6.46)	(4.82)	(0.55)	(-1.61)	(0.12)	(-0.92)	(-0.08)
WEATHERFORD INTL.	0.0074	1.3152***	0.5462***	-0.0115	0.0490	-0.4222**	-0.4295**	-0.0025
	(0.14)	(9.20)	(7.15)	(-0.26)	(0.46)	(-2.25)	(-2.06)	(-0.14)
Oil Equipment & Services Average	-0.0550	1.1269	0.3947	0.0885	0.0307	-0.0030	-0.2224	0.0173
Pipelines								
ENBRIDGE ENERGY PTNS.LP	-0.3832	0.4123	0.2388	-0.7922***	1.2271***	-2.9633***	1.7872**	0.1103
	(-0.95)	(1.03)	(1.03)	(-2.72)	(2.67)	(-2.58)	(2.35)	(0.99)
OGE ENERGY	0.0124	0.5600***	0.1233**	0.0555	-0.0506	0.1974	-0.1235	-0.0040
	(0.30)	(4.81)	(1.97)	(1.45)	(-0.57)	(1.34)	(-0.73)	(-0.29)
PLAINS ALL AMER.PIPE.LP. UNIT	-0.0699	0.8168***	0.2332***	0.0295	-0.1477	0.2879	0.0364	0.0207
	(-1.23)	(4.53)	(2.67)	(0.58)	(-1.39)	(1.61)	(0.17)	(1.10)
TC PIPELINES	-0.0132	0.3571***	0.1555***	-0.0416	0.0391	0.0474	0.1981	0.0050
	(-1.55)	(4.14)	(6.75)	(2.90)	(-0.54)	(2.22)	(5.69)	(1.88)
WILLIAMS	-0.0849	2.0112**	-0.5832	0.3956	0.4811	1.1545	1.0248	0.0174
	(-0.15)	(2.33)	(-1.30)	(1.38)	(0.49)	(0.85)	(0.85)	(0.10)
Pipelines Average	-0.1077	0.8315	0.0335	-0.0707	0.3098	-0.2552	0.5846	0.0299
Royalty Trusts								
BP PRUDEHOE BAY RTY. TST.	-0.0174	0.1632	0.4761***	0.0530	-0.1153	-0.1867	0.2178	0.0104
	(-0.36)	(1.22)	(7.58)	(1.44)	(-1.29)	(-1.14)	(1.12)	(0.65)
CROSS TIMBERS RTY.UNT.	-0.1086*	0.2517*	0.3483***	0.1434***	-0.1569	0.2184	0.0802	0.0373**
	(-1.96)	(1.72)	(4.98)	(3.61)	(-1.56)	(1.21)	(0.39)	(1.97)
DOMIONION RES. BLK. TST.	1.1100**	-1.1627	2.2855***	1.1164*	-0.7661	-2.1292	0.7216	-0.4372**
	(2.10)	(-0.88)	(3.07)	(1.81)	(-0.57)	(-0.92)	(0.26)	(-2.31)
HUGOTON ROYALTY TST.	-0.7258***	0.0137	0.1527	0.3431***	2.1398***	0.0758	1.7007***	0.2043***
	(-4.73)	(0.04)	(0.81)	(2.74)	(6.17)	(0.08)	(2.73)	(4.41)

Company name	Intercept α_{st}	Market $\beta_{1,i,st}$	Oil price $\beta_{2,i,st}$	Gas price $\beta_{3,i,st}$	Interest rate $\beta_{4,i,st}$	Size $\beta_{5,i,st}$	B/M $\beta_{6,i,st}$	VIX $\beta_{7,i,st}$
PERMIAN BASIN RTY.TST.	-0.1703**	0.9399***	0.1550	0.0044	0.6436*	-0.6144**	-0.51850*	0.0548**
	(-2.19)	(4.30)	(1.12)	(0.07)	(1.78)	(-2.16)	(-1.69)	(2.04)
SABINE ROYALTY TST.	-0.0726	0.7692*	0.5658***	0.2100*	0.1565	-0.4318	-1.4784**	0.0269
	(-0.53)	(1.77)	(3.07)	(1.87)	(0.55)	(-0.64)	(-2.10)	(0.58)
SAN JUAN BASIN RTY.TST.	-0.0708	0.4022***	0.2043***	0.2124***	0.1433	-0.1026	0.0222	0.0252
	(-1.45)	(3.12)	(3.23)	(5.64)	(1.51)	(-0.61)	(0.12)	(1.53)
Royalty Trusts Average	-0.0079	0.1967	0.5982	0.2975	0.2921	-0.4529	0.1065	-0.0112

Table A 3 Risk Factor Sensitivities of U.S. Oil and Gas Firms in the Low Volatility Regime: Firm Level

Risk factor sensitivities, in the low volatility regime of the U.S. oil and gas firms in our sample, for the following subsectors: Exploration and Production, Integrated Oil and Gas, Oil Equipment and Services, Pipelines and Royalty Trusts. Our regression model is as follows:

$$R_{it} - R_{ft} = \alpha_{st} + \beta_{1,i,st}(R_{mt} - R_{ft}) + \beta_{2,i,st}R_{Oil,t} + \beta_{3,i,st}R_{Gas,t} + \beta_{4,i,st}R_{Int,t} + \beta_{5,i,st}SMB_t + \beta_{6,i,st}HML_t + \beta_{7,i,st}Ln_{VIX,t} + \varepsilon_{i,st}$$

Company name	Intercept α_{st}	Market $\beta_{1,i,st}$	Oil price $\beta_{2,i,st}$	Gas price $\beta_{3,i,st}$	Interest rate $\beta_{4,i,st}$	Size $\beta_{5,i,st}$	B/M $\beta_{6,i,st}$	VIX $\beta_{7,i,st}$
Exploration & Production								
ANADARKO PETROLEUM	-0.0165	0.9385***	0.4234***	0.0588*	0.0266	-0.3200	0.0699	0.0059
	(-0.41)	(7.93)	(6.37)	(1.68)	(0.37)	(-1.28)	(0.28)	(0.43)
APACHE	-0.1217**	0.4406***	0.6466***	0.0383	-0.1887	-0.0643	-0.1518	0.0421**
	(-2.40)	(3.28)	(7.98)	(0.97)	(-1.43)	(-0.38)	(-0.81)	(2.47)
ATWOOD OCEANICS	0.1095	-0.2367	-0.7150***	0.3489***	0.5503	0.9793***	1.0934***	-0.0098
	(0.53)	(-0.57)	(-2.72)	(3.32)	(1.62)	(2.81)	(2.59)	(-0.14)
CABOT OIL & GAS 'A'	-0.0660	0.4521***	0.3825***	0.0943***	-0.0421	0.3482**	0.9447***	0.0269*
	(-1.55)	(4.14)	(6.75)	(2.90)	(-0.54)	(2.22)	(5.69)	(1.88)
CALLON PTL.DEL.	-0.1889*	1.0377***	0.4016***	0.2265***	0.2076	-0.8491**	-0.9324***	0.0725**
	(-1.88)	(3.32)	(3.02)	(3.24)	(1.01)	(-2.51)	(-2.70)	(2.04)
CHESAPEAKE ENERGY	0.0534	1.0142***	0.5282***	0.1857***	-0.0772	-0.2595	-0.4798	-0.0179
	(0.94)	(6.20)	(6.19)	(3.62)	(-0.69)	(-0.84)	(-1.50)	(-0.93)
CLAYTON WILLIAMS EN.	-0.2874***	-1.1115***	2.0819***	0.0294	-0.2785*	-1.737***	-2.5726***	0.1336***
	(-5.06)	(-7.48)	(29.90)	(0.75)	(-1.88)	(-9.08)	(-11.18)	(6.98)
COMSTOCK RES.	-0.0389	1.5301***	0.1998**	0.2461***	-0.0777	-1.3346***	-0.1074	0.0147
	(-0.65)	(7.72)	(2.24)	(5.44)	(-0.67)	(-5.19)	(-0.38)	(0.71)
DENBURY RES.	0.0416	0.4394***	0.8041***	0.2006***	0.2038**	0.4338*	-0.7638***	-0.0113
	(0.75)	(2.68)	(9.02)	(3.60)	(2.09)	(1.72)	(-3.02)	(-0.58)
DEVON ENERGY	-0.0508	0.2729**	0.6294***	0.0531	-0.1471	0.4235**	0.4607**	0.0212
	(-0.97)	(1.96)	(8.51)	(1.20)	(-1.34)	(2.57)	(2.06)	(1.20)
DIAMOND OFFS.DRL.	0.0963***	1.6724***	0.5904***	0.0455***	0.1067**	-0.2353***	-0.8026***	-0.0505***
	(3.65)	(25.08)	(17.43)	(2.60)	(2.25)	(-3.39)	(-8.71)	(-5.73)

Company name	Intercept α_{st}	Market $\beta_{1,i,st}$	Oil price $\beta_{2,i,st}$	Gas price $\beta_{3,i,st}$	Interest rate $\beta_{4,i,st}$	Size $\beta_{5,i,st}$	B/M $\beta_{6,i,st}$	VIX $\beta_{7,i,st}$
ENERGEN	0.0057	0.1004	0.4238***	0.0973**	0.4784***	-1.0232***	1.4654***	-0.0051
	(0.08)	(0.66)	(5.75)	(2.21)	(4.65)	(-4.64)	(7.25)	(-0.20)
EOG RES.	0.0698	0.9794***	0.4012***	0.1008**	0.0769	-0.5591**	0.0526	-0.0221
	(1.45)	(6.85)	(5.53)	(2.41)	(0.83)	(-2.21)	(0.20)	(-1.34)
EQT	0.0048	0.3594***	-0.0279	0.0930***	-0.0081	0.0713	0.1028	0.0020
	(0.13)	(2.68)	(-0.50)	(3.63)	(-0.09)	(0.46)	(0.50)	(0.16)
GOODRICH PTL.	0.1919**	1.5588***	0.4435***	0.1569**	0.3396*	-0.8564**	-0.3407	-0.0658**
	(2.05)	(5.47)	(3.24)	(2.28)	(1.74)	(-2.04)	(-0.85)	(-2.07)
MARATHON OIL	0.1696	0.8553***	0.2908***	-0.0789	-0.2921	0.0157	0.3876	-0.0399
	(0.13)	(0.00)	(0.01)	(0.21)	(0.14)	(0.96)	(0.22)	(0.26)
NEWFIELD EXPLORATION	-0.4578***	1.7833***	-0.1557	0.7055***	-0.2657	1.4674***	0.1729	0.0966**
	(-4.03)	(5.44)	(-0.94)	(9.43)	(-1.58)	(3.99)	(0.50)	(2.54)
NOBLE ENERGY	0.1133*	0.7210***	0.7683***	0.1201**	-0.1117	-0.0154	-0.1225	-0.0481**
	(1.75)	(4.66)	(8.06)	(2.44)	(-1.07)	(-0.07)	(-0.54)	(-2.24)
OCCIDENTAL PTL.	-0.0137	0.7747***	0.3952***	0.0188	-0.0243	-0.1391	-0.0963	0.0067
	(-0.41)	(8.25)	(8.36)	(0.70)	(-0.36)	(-0.90)	(-0.50)	(0.60)
PANHANDLE OIL & GAS	-0.1551***	0.3752***	0.1771***	0.2567**	-0.1067***	-0.2751***	-0.3211***	0.0579***
	(-10.33)	(12.08)	(10.43)	(30.54)	(-3.60)	(-5.78)	(-5.92)	(12.52)
PARKER DRILLING	0.0279	2.2345***	0.7106***	0.3942***	0.1033**	0.3477***	0.2098***	0.0498***
	(1.43)	(57.43)	(46.87)	(33.60)	(2.34)	(6.26)	(3.56)	(7.94)
PETROQUEST ENERGY	-0.0083	0.5442*	0.9559***	0.1280	-0.2348	-1.5546***	0.1213	0.0009
	(-0.08)	(1.69)	(5.42)	(1.48)	(-1.45)	(-3.17)	(0.29)	(0.02)
PIONEER NTRL.RES.	-0.0078	0.8894***	0.4506***	0.1038	0.2542***	-0.3782	1.8091***	0.0105
	(-0.13)	(5.84)	(3.45)	(1.28)	(2.69)	(-1.38)	(9.26)	(0.51)
RANGE RES.	0.8620*	1.8346***	0.7201***	0.4599***	-3.4143***	1.5759***	-1.8444***	-0.2431
	(1.65)	(5.02)	(4.30)	(3.16)	(-5.71)	(3.60)	(-4.03)	(-1.49)
SM ENERGY	-0.0391	0.0015	0.9986***	0.1892**	0.2518	0.1599	0.5931	0.0076
	(-0.34)	(0.00)	(6.73)	(2.31)	(0.91)	(0.27)	(1.34)	(0.19)

Company name	Intercept α_{st}	Market $\beta_{1,i,st}$	Oil price $\beta_{2,i,st}$	Gas price $\beta_{3,i,st}$	Interest rate $\beta_{4,i,st}$	Size $\beta_{5,i,st}$	B/M $\beta_{6,i,st}$	VIX $\beta_{7,i,st}$
STONE ENERGY	-0.1470*	1.3263***	0.3679***	0.1343**	0.0852	-0.2105	-0.5492**	0.0520*
	(-1.86)	(6.72)	(4.03)	(2.53)	(0.65)	(-0.84)	(-2.01)	(1.94)
SUPERIOR ENERGY SVS.	0.0157	5.0316***	0.0277	0.3084	0.3647	-0.1155	-2.5084***	-0.0113
	(1.24)	(5.36)	(5.15)	(0.59)	(0.02)	(-0.57)	(-0.87)	(-1.14)
SWIFT ENERGY	0.0156	1.0955***	0.4127***	0.2249***	0.0095	0.1709	0.0334	-0.0072
	(0.19)	(5.10)	(3.35)	(3.83)	(0.06)	(0.59)	(0.11)	(-0.26)
TRANSOCEAN	0.1261***	-0.1167***	0.7386***	-0.1389***	3.7928***	0.9317***	-2.0603***	-0.0702***
	(385.61)	(-125.33)	(1258.21)	(-402.32)	(1959.81)	(420.94)	(-2218.82)	(-735.18)
UNIT	0.0091	0.3098	0.9609***	1.2348***	4.3432***	2.5422***	-0.2959	0.0211
	(0.04)	(0.54)	(3.76)	(7.09)	(5.87)	(4.16)	(-0.49)	(0.27)
VAALCO ENERGY	-0.0669	0.6139**	0.2782**	0.0655	0.1102	-0.3965	0.2986	0.0167
	(-0.69)	(2.13)	(2.27)	(0.98)	(0.69)	(-1.32)	(0.87)	(0.52)
Exploration & Production Average	0.0079	0.8943	0.4939	0.1968	0.1947	-0.0276	-0.1979	0.0012
Integrated Oil & Gas								
CHEVRON	0.0241	0.8989***	0.3046***	0.0263	-0.0429	-0.2153	-0.1667	-0.0085
	(0.73)	(9.10)	(6.71)	(0.98)	(-0.77)	(-1.55)	(-0.92)	(-0.74)
CONOCOPHILLIPS	-0.1156	0.1238	0.4964***	-0.0274	0.0520	0.3218**	-0.6333**	0.0353
	(-1.58)	(0.77)	(7.54)	(-0.58)	(0.62)	(2.31)	(-2.21)	(1.53)
ENI SPA SPN.ADR 1:2	-0.0471***	1.0759***	0.3058***	0.0254***	0.0269***	-0.4085***	0.0350***	0.0069***
	(-89.30)	(1359.52)	(619.48)	(94.11)	(32.71)	(-411.83)	(22.80)	(42.69)
EXXON MOBIL	0.0169	-0.0199	0.1600***	0.2984***	-0.3251***	-0.3914***	0.1605	0.0031
	(0.48)	(-0.29)	(4.13)	(11.88)	(-6.28)	(-4.21)	(1.31)	(0.28)
HESS	0.0670	1.0268***	0.5044***	0.0287	0.0252	-0.1997	0.2167	-0.0237
	(1.24)	(6.12)	(6.54)	(0.68)	(0.28)	(-0.85)	(0.77)	(-1.23)
MURPHY OIL	-0.0347	0.9279***	0.5765***	0.0730	-0.2064	-0.0272	-0.6908***	-0.0002
	(-0.56)	(4.15)	(4.97)	(1.17)	(-1.34)	(-0.10)	(-2.78)	(-0.01)
SUNCOR ENERGY INCO.	0.0781	1.0764***	0.4290***	0.0249	0.0024	-0.1076	-0.2221	-0.0246
	(1.24)	(5.36)	(5.15)	(0.59)	(0.02)	(-0.57)	(-0.87)	(-1.14)

Company name	Intercept α_{st}	Market $\beta_{1,i,st}$	Oil price $\beta_{2,i,st}$	Gas price $\beta_{3,i,st}$	Interest rate $\beta_{4,i,st}$	Size $\beta_{5,i,st}$	B/M $\beta_{6,i,st}$	VIX $\beta_{7,i,st}$
Integrated Oil & Gas Average	-0.0016	0.729982	0.396675	0.064185	-0.066828	-0.146859	-0.185821	-0.001665
Oil Equipment & Services								
BAKER HUGHES	-0.0398	0.5226**	-0.2278**	0.2662***	0.5817***	0.5738**	0.3312	0.0291
	(-0.51)	(2.51)	(-2.13)	(4.18)	(2.92)	(2.18)	(0.99)	(1.14)
BUCKEYE PARTNERS	-0.1784**	-0.7024***	0.3942***	-0.0653	1.4334***	-1.7167**	0.2203	0.0702**
	(-2.07)	(-4.47)	(4.26)	(-0.77)	(8.01)	(-2.51)	(0.50)	(2.54)
ENSCO CLASS A	-0.0392	4.8950***	-1.4852***	0.4528***	0.6871***	2.4768***	0.2345	-0.0426*
	(-0.50)	(68.30)	(-17.12)	(13.69)	(4.81)	(12.03)	(1.11)	(-1.79)
HALLIBURTON	-0.1435**	0.9249***	0.2837***	0.0997**	0.0181	-0.0721	0.2458	0.0582***
	(-2.30)	(5.30)	(3.70)	(2.05)	(0.15)	(-0.29)	(0.97)	(2.68)
HELMERICH & PAYNE	0.1470	1.1679***	0.5473***	0.0468	-0.0540	-0.7451**	-0.4293	-0.0518*
	(1.65)	(4.64)	(4.26)	(0.64)	(-0.28)	(-2.18)	(-1.34)	(-1.73)
ION GEOPHYSICAL	-0.0972	1.3934***	0.2206	0.0544	-0.4254*	-0.2330	0.3965	0.0332
	(-0.74)	(5.27)	(1.58)	(0.62)	(-1.80)	(-0.59)	(1.07)	(0.75)
KEY ENERGY SVS.	-0.0250	2.4103***	0.2849***	0.0951***	-0.3380***	-0.7924***	-0.9697***	0.0207***
	(-1.15)	(43.23)	(9.86)	(4.69)	(-5.28)	(-12.34)	(-13.24)	(2.94)
NABORS INDUSTRIES	-0.1484***	1.3030***	0.4369***	0.1789***	0.0958***	0.1500***	0.6745***	0.0733***
	(-215.79)	(607.57)	(307.96)	(383.47)	(109.15)	(48.77)	(170.40)	(296.63)
NOBLE CORPORATION	0.0254	0.9624***	0.4918***	0.0510	-0.0401	-0.2891	0.0812	-0.0099
	(0.49)	(6.68)	(6.98)	(1.28)	(-0.41)	(-1.31)	(0.30)	(-0.56)
NATIONAL OILWELL VARCO	-0.1883***	0.2105***	-3.24E-05	0.1444***	0.8244***	0.1115**	1.2541***	0.0977***
	(-9.90)	(4.30)	(-0.00)	(6.58)	(36.58)	(2.41)	(24.45)	(15.23)
OCEANEERING	-0.0011	1.3314***	0.5323***	0.0129	-0.1572	0.0176	-0.1304	-0.0013
	(-0.02)	(7.65)	(6.37)	(0.24)	(-1.46)	(0.07)	(-0.44)	(-0.07)
ROWAN COMPANIES CL.A	0.0454	1.2973***	0.5626***	0.0462	0.1786	-0.4403*	-0.4195**	-0.0221
	(0.80)	(7.93)	(6.88)	(0.91)	(1.17)	(-1.89)	(-2.07)	(-1.18)
RPC	-0.1135***	-0.7075***	0.5792***	0.2209***	-0.3013***	0.8644***	-0.5975***	0.0462***
	(-10.68)	(-29.26)	(39.99)	(28.40)	(-13.60)	(37.12)	(-17.08)	(13.08)

Company name	Intercept α_{st}	Market $\beta_{1,i,st}$	Oil price $\beta_{2,i,st}$	Gas price $\beta_{3,i,st}$	Interest rate $\beta_{4,i,st}$	Size $\beta_{5,i,st}$	B/M $\beta_{6,i,st}$	VIX $\beta_{7,i,st}$
SCHLUMBERGER	0.1958***	1.4184***	0.4728***	-0.1116**	0.0512	-0.9194***	-0.2782	-0.0649**
	(2.67)	(8.42)	(5.16)	(-2.52)	(0.37)	(-4.44)	(-0.95)	(-2.55)
TIDEWATER	0.1603***	1.2660***	-0.0470**	0.2406***	-0.6614***	-0.3202***	0.2517***	-0.0462***
	(6.85)	(31.44)	(-2.54)	(14.97)	(-14.55)	(-6.73)	(3.80)	(-5.80)
WEATHERFORD INTL.	-0.1945***	2.4177***	-0.3370***	0.3296***	-1.1556***	6.1109***	4.7620***	0.0511***
	(-4.02)	(43.26)	(-12.64)	(16.32)	(-19.64)	(55.14)	(55.24)	(3.18)
Oil Equipment & Services Average	-0.0372	1.2569	0.1693	0.1289	0.0461	0.2985	0.3517	0.0151
Pipelines								
ENBRIDGE ENERGY PTNS.LP	-0.0438	0.2794***	0.1688***	0.0193	-0.0394	-0.0146	-0.1316	0.0148
	(-1.14)	(2.71)	(3.45)	(0.71)	(-0.57)	(-0.12)	(-0.92)	(1.13)
OGE ENERGY	-0.0204	0.4794***	-0.0233	-0.0696***	-0.1256***	-0.3849***	0.4230***	0.0068
	(-0.61)	(8.31)	(-1.08)	(-6.00)	(-4.47)	(-5.50)	(6.77)	(0.59)
PLAINS ALL AMER.PIPE.LP. UNIT	0.0388	-0.0033	0.0289	-0.0778*	0.1334	-0.5732***	0.3830**	-0.0078
	(0.62)	(-0.02)	(0.40)	(-1.69)	(1.31)	(-2.58)	(2.09)	(-0.38)
TC PIPELINES	-0.0711***	0.2293***	0.1319***	0.0122*	0.0471***	0.2084***	-0.3828***	0.0283***
	(-0.71)	(4.02)	(1.73)	(5.12)	(0.63)	(-1.04)	(-2.77)	(0.91)
WILLIAMS	0.0734*	0.9287***	0.4523***	0.0931**	0.1014	-0.1618	-0.4699**	-0.0236
	(1.68)	(7.20)	(7.09)	(2.46)	(1.22)	(-0.85)	(-2.44)	(-1.57)
Pipelines Average	-0.0046	0.3827	0.1517	-0.0046	0.0234	-0.1852	-0.0356	0.0037
Royalty Trusts								
BP PRUDEHOE BAY RTY. TST.	-0.3266***	-0.6622***	-0.7575***	-0.0777	2.1877***	0.3913**	-0.5808***	0.0983***
	(-10.67)	(-7.92)	(-12.87)	(-1.43)	(29.57)	(2.14)	(-6.27)	(10.89)
CROSS TIMBERS RTY.UNT.	-0.4453***	1.4058***	-0.4989***	-0.9779***	3.0258***	-0.4819**	0.9632***	0.1055***
	(-3.62)	(18.71)	(-13.01)	(-19.62)	(32.47)	(-2.46)	(5.81)	(3.14)
DOMIONION RES. BLK. TST.	-0.1094**	0.3316**	0.1981***	0.0854**	0.0908	0.0943	0.1973	0.0359**
	(-2.09)	(2.41)	(2.79)	(2.11)	(0.87)	(0.52)	(1.00)	(2.07)
HUGOTON ROYALTY TST.	-0.0036	0.1141	0.2513***	0.2933***	-0.1124	0.0248	-0.0523	0.0029

Company name	Intercept α_{st}	Market $\beta_{1,i,st}$	Oil price $\beta_{2,i,st}$	Gas price $\beta_{3,i,st}$	Interest rate $\beta_{4,i,st}$	Size $\beta_{5,i,st}$	B/M $\beta_{6,i,st}$	VIX $\beta_{7,i,st}$
	(-0.07)	(0.78)	(3.53)	(6.72)	(-1.16)	(0.14)	(-0.26)	(0.15)
PERMIAN BASIN RTY.TST.	0.0681	-0.3697**	0.3978***	0.1025**	-0.1399*	0.5238**	0.3328	-0.0195
	(1.13)	(-2.25)	(4.84)	(2.13)	(-1.69)	(2.03)	(1.32)	(-1.00)
SABINE ROYALTY TST.	-0.0333	0.2156	0.2522***	0.0597*	0.0307	0.1659	0.2437	0.0135
	(-0.78)	(1.55)	(2.89)	(1.75)	(0.42)	(1.11)	(1.30)	(0.96)
SAN JUAN BASIN RTY.TST.	-0.3081**	0.6768***	1.3686***	0.4249***	-0.1522	-1.4799***	0.0816	0.0354
	(-2.25)	(4.86)	(6.89)	(2.59)	(-1.34)	(-4.31)	(0.27)	(0.82)
Royalty Trusts Average	-0.1655	0.2446	0.1731	-0.0128	0.7044	-0.1088	0.16931	0.0388

Table A 4 Transition Probabilities and Expected Regime Durations: Subsector Level

Markov transition probabilities and expected regime durations for the four U.S. oil and gas subsectors, Royalty Trusts and the U.S. oil and gas sector as a whole.

		Markov transition probabilities		Expected regime durations	
Subsector		High volatility regime	Low volatility regime	High volatility regime	Low volatility regime
Exploration and production	High	0.9685	0.0315	31.7197	45.3260
	Low	0.0221	0.9779		
Integrated oil and gas	High	0.9620	0.0380	26.2917	64.3369
	Low	0.0155	0.9845		
Oil equipment and services	High	0.9295	0.0705	14.1873	1.0000
	Low	0.9999	0.0001		
Pipelines	High	0.8432	0.1568	6.3771	2.2066
	Low	0.4532	0.5468		
Royalty Trusts	High	0.9122	0.0878	11.3843	43.4876
	Low	0.0230	0.9770		
U.S. Oil and gas sector	High	0.9680	0.0320	31.2253	46.0065
	Low	0.0217	0.9783		

Table A 5 Transition Probabilities and Expected Regime Durations: Firm Level

Markov transition probabilities and expected regime durations for the 66 U.S. oil and gas companies included in our sample.

		Markov transition probabilities		Expected regime durations	
Company name		High volatility regime	Low volatility regime	High volatility regime	Low volatility regime
ANADARKO PETROLEUM	High	0.8773	0.1227	8.1499	27.5499
	Low	0.0363	0.9637		
APACHE	High	0.4447	0.5553	1.8010	4.6703
	Low	0.2141	0.7859		
ATWOOD OCEANICS	High	0.8782	0.1218	8.2113	1.0000
	Low	1.0000	0.0000		
BAKER HUGHES	High	0.4470	0.5530	1.8084	1.0000
	Low	1.0000	0.0000		
BP PRUDEHOE BAY RTY. TST.	High	0.9036	0.0964	10.3735	1.1941
	Low	0.8375	0.1625		
BUCKEYE PARTNERS	High	0.9722	0.0278	36.0284	3.6732
	Low	0.2722	0.7278		
CABOT OIL & GAS 'A'	High	0.2839	0.7161	1.3964	1.0000
	Low	1.0000	0.0000		
CALLON PTL.DEL.	High	0.8552	0.1448	6.9047	12.8843
	Low	0.0776	0.9224		

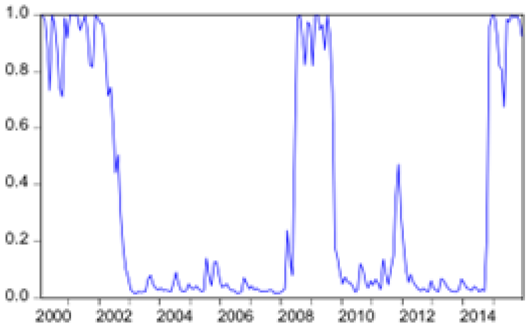
Company name		Markov transition probabilities High volatility regime	Low volatility regime	Expected regime durations High volatility regime	Low volatility regime
CHESAPEAKE ENERGY	High	0.9852	0.0148	67.5902	93.9971
	Low	0.0106	0.9894		
CHEVRON	High	0.9475	0.0525	19.0375	65.2793
	Low	0.0153	0.9847		
CLAYTON WILLIAMS EN.	High	0.9091	0.0909	10.9979	1.6237
	Low	0.6159	0.3841		
COMSTOCK RES.	High	0.8436	0.1564	6.3936	17.6901
	Low	0.0565	0.9435		
CONOCOPHILLIPS	High	0.6692	0.3308	3.0228	1.7461
	Low	0.5727	0.4273		
CROSS TIMBERS RTY. UNT.	High	0.9943	0.0057	176.6287	8.9065
	Low	0.1123	0.8877		
DENBURY RES.	High	0.8234	0.1766	5.6633	4.4761
	Low	0.2234	0.7766		
DEVON ENERGY	High	0.3933	0.6067	1.6482	2.0393
	Low	0.4904	0.5096		
DIAMOND OFFS.DRL.	High	0.8620	0.1380	7.2474	1.4146
	Low	0.7069	0.2931		
DOM.RES.BLK.WARRIOR UTS.	High	0.8392	0.1608	6.2182	35.8175
	Low	0.0279	0.9721		
ENBRIDGE ENERGY PTNS.LP	High	0.8617	0.1383	7.2308	114.6223
	Low	0.0087	0.9913		
ENERGEN	High	0.6542	0.3458	2.8921	1.0875
	Low	0.9196	0.0804		
ENI SPA SPN.ADR 1:2	High	0.9424	0.0576	17.3524	1.3131
	Low	0.7615	0.2385		
ENSCO CLASS A	High	0.9695	0.0305	32.8072	1.9558
	Low	0.5113	0.4887		
EOG RES.	High	0.9587	0.0413	24.2063	71.1619
	Low	0.0140	0.9860		
EQT	High	0.9694	0.0306	32.7316	15.8992
	Low	0.0629	0.9371		
EXXON MOBIL	High	0.8196	0.1804	5.5424	1.1773
	Low	0.8494	0.1506		
GOODRICH PTL.	High	0.8474	0.1526	6.5529	12.3936
	Low	0.0807	0.9193		
HALLIBURTON	High	0.2922	0.7078	1.4128	3.3455
	Low	0.2989	0.7011		
HELMERICH & PAYNE	High	0.0000	1.0000	1.0000	1.1054
	Low	0.9047	0.0953		
HESS	High	0.9515	0.0485	20.5988	33.6549
	Low	0.0297	0.9703		
HUGOTON ROYALTY TST.	High	0.8615	0.1385	7.2214	43.9985

Company name		Markov transition probabilities		Expected regime durations	
		High volatility regime	Low volatility regime	High volatility regime	Low volatility regime
	Low	0.0227	0.9773		
ION GEOPHYSICAL	High	0.9493	0.0507	19.7289	19.3628
	Low	0.0517	0.9483		
KEY ENERGY SVS.	High	0.8148	0.1852	5.3983	1.6000
	Low	0.6250	0.3750		
MARATHON OIL	High	0.6086	0.3914	2.5550	1.0000
	Low	1.0000	0.0000		
MURPHY OIL	High	0.3488	0.6512	1.5356	1.0000
	Low	1.0000	0.0000		
NABORS INDUSTRIES	High	0.9477	0.0523	19.1082	1.0001
	Low	0.9999	0.0001		
NEWFIELD EXPLORATION	High	0.8927	0.1073	9.3208	1.5601
	Low	0.6410	0.3590		
NOBLE CORPORATION	High	0.9239	0.0761	13.1320	28.4780
	Low	0.0351	0.9649		
NOBLE ENERGY	High	0.3581	0.6419	1.5580	1.6622
	Low	0.6016	0.3984		
NATIONAL OILWELL VARCO	High	0.9106	0.0894	11.1902	1.4430
	Low	0.6930	0.3070		
OCCIDENTAL PTL.	High	0.7069	0.2931	3.4122	26.5125
	Low	0.0377	0.9623		
OCEANEERING	High	0.6324	0.3676	2.7200	10.1646
	Low	0.0984	0.9016		
OGE ENERGY	High	0.7072	0.2928	3.4155	1.2374
	Low	0.8081	0.1919		
PANHANDLE OIL & GAS	High	0.8160	0.1840	5.4355	1.0001
	Low	1.0000	0.0000		
PARKER DRILLING	High	0.9358	0.0642	15.5755	1.1432
	Low	0.8747	0.1253		
PERMIAN BASIN RTY.TST.	High	0.2760	0.7240	1.3812	1.6837
	Low	0.5939	0.4061		
PETROQUEST ENERGY	High	0.6815	0.3185	3.1396	5.7357
	Low	0.1743	0.8257		
PIONEER NTRL.RES.	High	0.4931	0.5069	1.9728	1.0000
	Low	1.0000	0.0000		
PLAINS ALL AMER.PIPE.LP.	High	0.4585	0.5415	1.8468	1.6602
	Low	0.6023	0.3977		
RANGE RES.	High	0.9943	0.0057	175.8516	12.8802
	Low	0.0776	0.9224		
ROWAN COMPANIES CL.A	High	0.0000	1.0000	1.0000	1.3431
	Low	0.7445	0.2555		

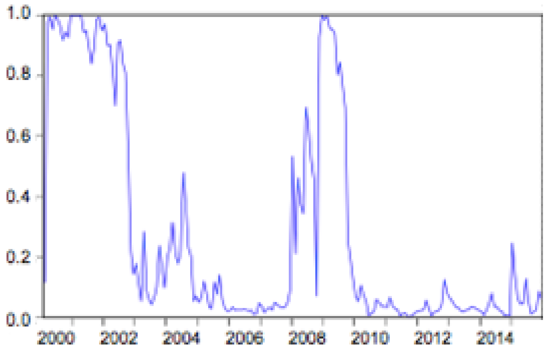
Company name		Markov transition probabilities: High volatility regime	Markov transition probabilities: Low volatility regime	Expected regime durations: High volatility regime	Expected regime durations: Low volatility regime
RPC	High	0.9367	0.0633	15.8082	1.9997
	Low	0.5001	0.4999		
SABINE ROYALTY TST.	High	0.6120	0.3880	2.5776	5.3129
	Low	0.1882	0.8118		
SAN JUAN BASIN RTY.TST.	High	0.9885	0.0115	87.1295	6.6747
	Low	0.1498	0.8502		
SCHLUMBERGER	High	0.3987	0.6013	1.6632	1.7170
	Low	0.5824	0.4176		
SM ENERGY	High	0.8055	0.1945	5.1425	3.5237
	Low	0.2838	0.7162		
STONE ENERGY	High	0.8166	0.1834	5.4520	28.6832
	Low	0.0349	0.9651		
SUNCOR ENERGY INCO.	High	0.7376	0.2624	3.8113	22.3451
	Low	0.0448	0.9552		
SUPERIOR ENERGY SVS.	High	0.8838	0.1162	8.6061	1.1816
	Low	0.8463	0.1537		
SWIFT ENERGY	High	0.7866	0.2134	4.6865	24.7073
	Low	0.0405	0.9595		
TC PIPELINES	High	0.8254	0.1746	5.7262	1.0268
	Low	0.9739	0.0261		
TIDEWATER	High	0.8687	0.1313	7.6137	1.5923
	Low	0.6280	0.3720		
TRANSOCEAN	High	0.9566	0.0434	23.0432	1.1260
	Low	0.8881	0.1119		
UNIT	High	0.9810	0.0190	52.6758	5.8971
	Low	0.1696	0.8304		
VAALCO ENERGY	High	0.0785	0.9215	1.0852	4.6067
	Low	0.2171	0.7829		
WEATHERFORD INTL.	High	0.9133	0.0867	11.5403	1.0000
	Low	1.0000	0.0000		
WILLIAMS	High	0.8469	0.1531	6.5324	31.5564
	Low	0.0317	0.9683		

Figure A 1 Filtered Regime Probabilities: Subsector Level

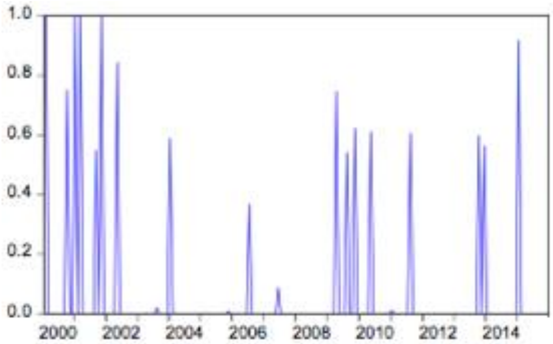
Filtered regime probabilities for exploration and production, integrated oil and gas, oil equipment and services, pipelines, Royalty Trusts and the U.S. oil and gas sector as a whole, where *P(s(t)=1)* is the probability of a firm being in the high volatility state at time *t* and *1-P(s(t))* is the probability of a firm being in the low volatility regime at time *t*.



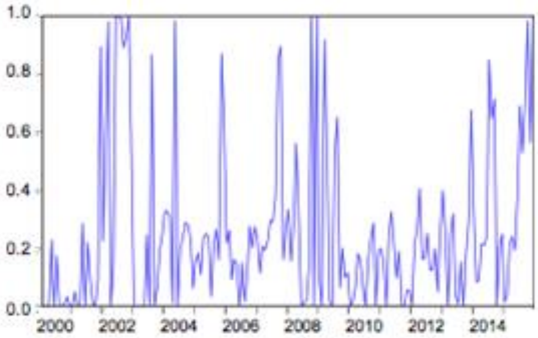
Exploration and Production



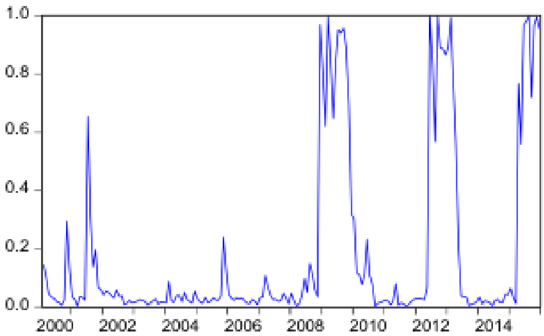
Integrated Oil and Gas



Oil Equipment and Services



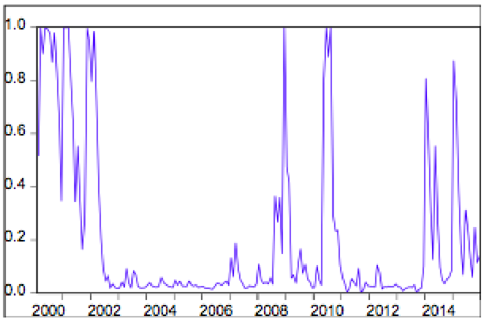
Pipelines



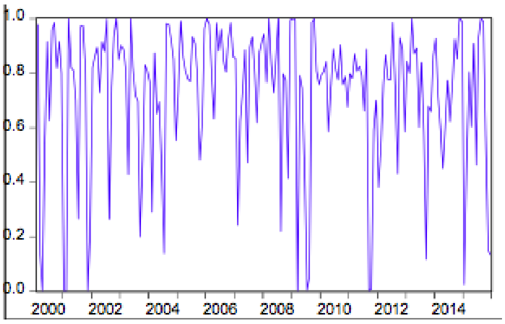
Royalty Trusts

Figure A 2 Filtered Regime Probabilities: Firm Level

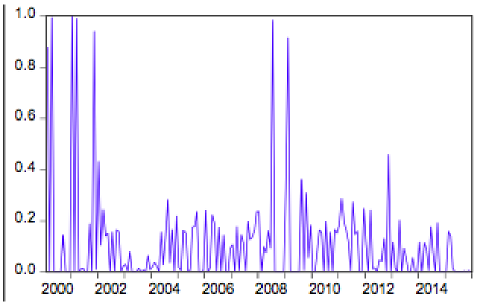
Filtered regime probabilities for the 66 U.S. oil and gas companies included in our sample, listed alphabetically. *P(s(t)=1)* is the probability of a firm being in the high volatility state at time *t* and *1-P(s(t))* is the probability of a firm being in the low volatility regime at time *t*.



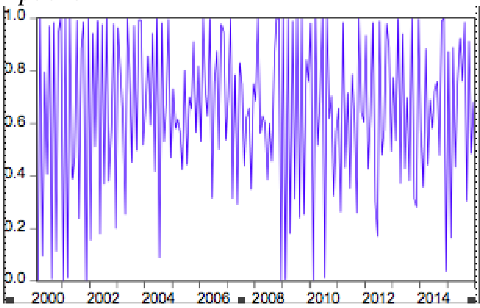
Anadarko Petroleum



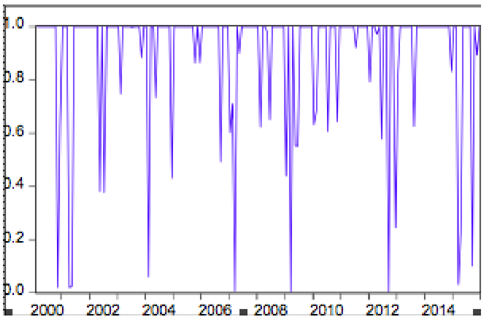
Apache



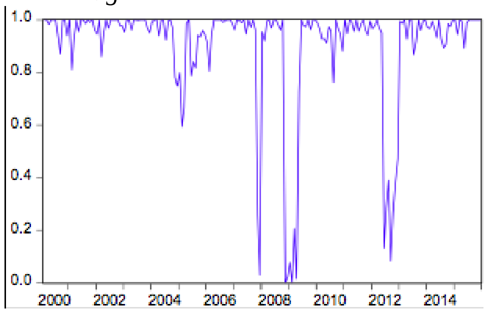
Atwood Oceanics



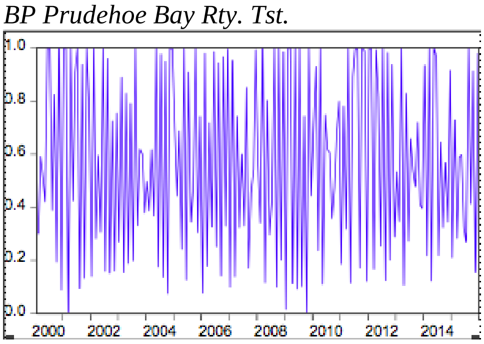
Baker Hughes



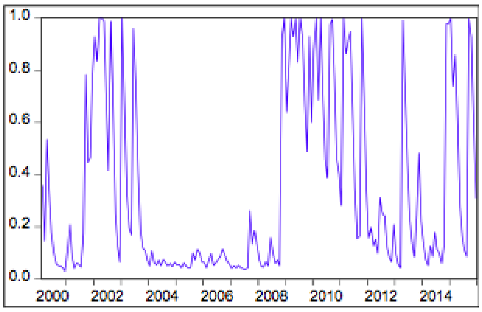
BP Prudehoe Bay Rty. Tst.



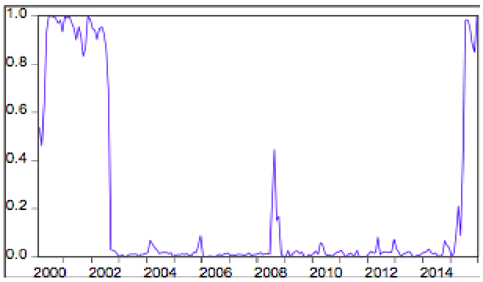
Buckeye Partners



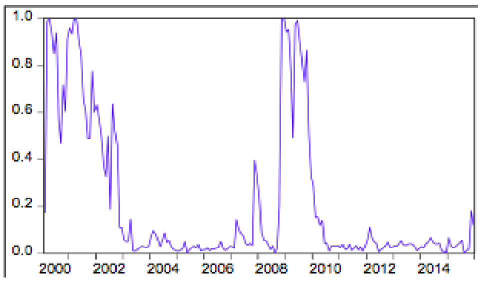
Cabot Oil and Gas



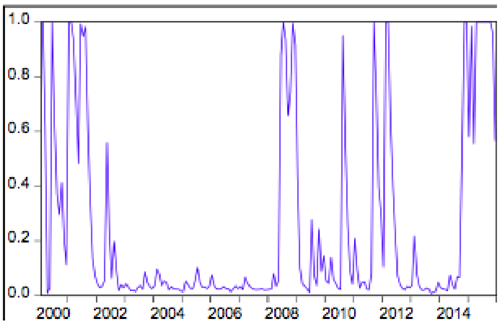
Callon Ptl. Del.



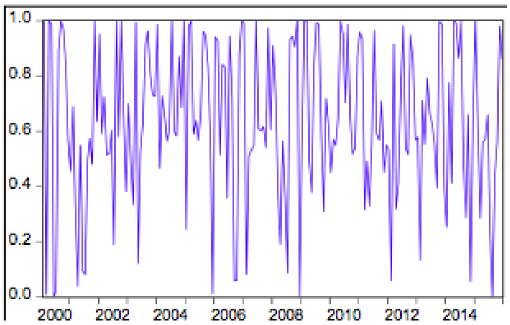
Chesapeake Energy



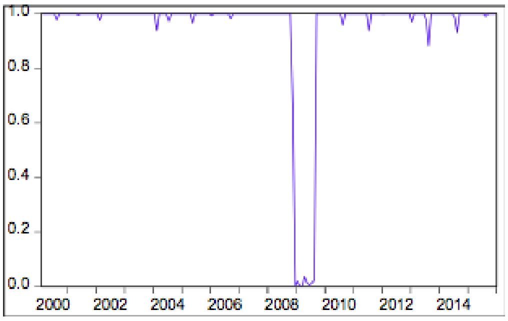
Chevron



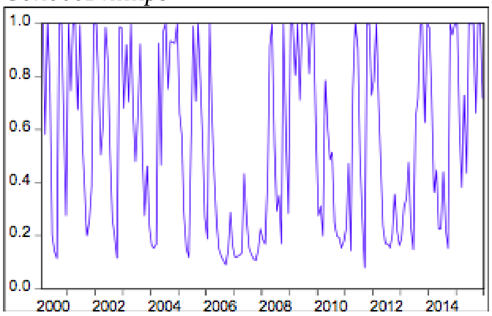
Comstock Res.



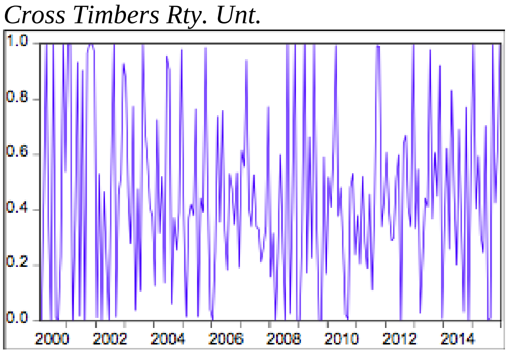
ConocoPhillips



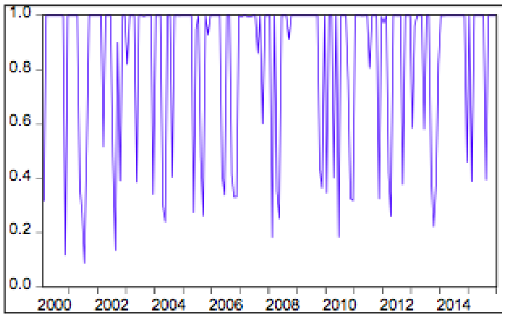
Cross Timbers Rty. Unt.



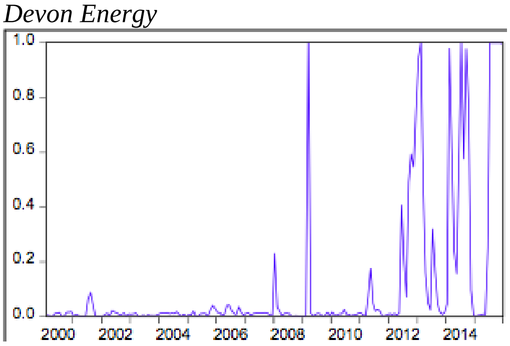
Denbury Res.



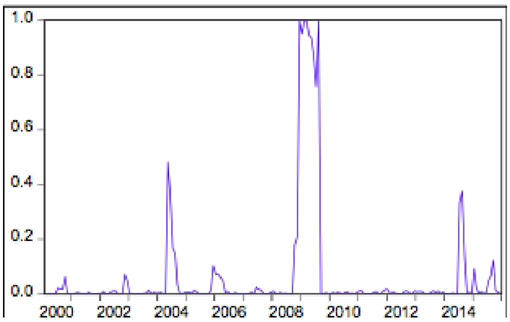
Devon Energy



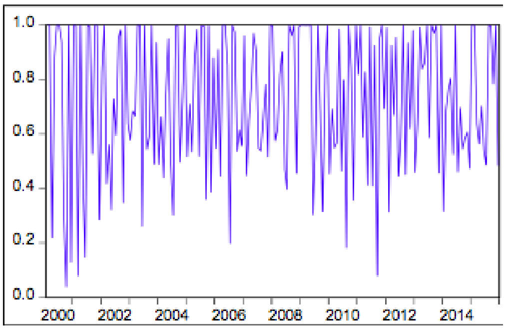
Diamond Offs. Drl.



Dom.Res.Blk. Warrior Uts.



Enbridge Energy Ptns. Lp.



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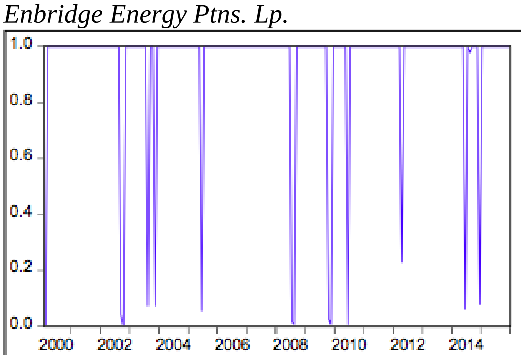

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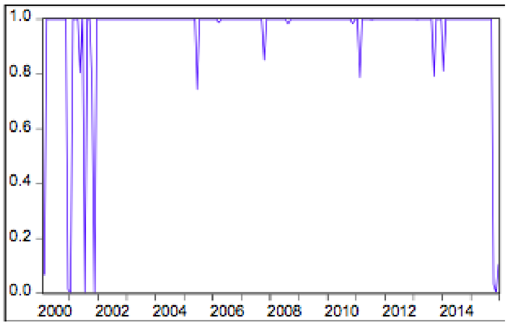

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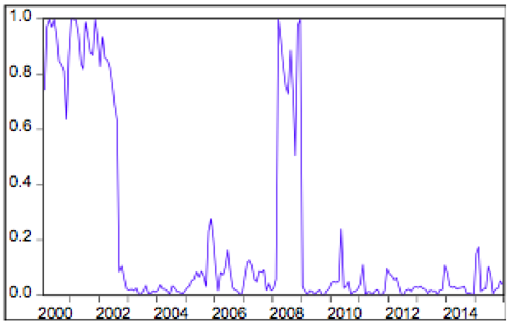
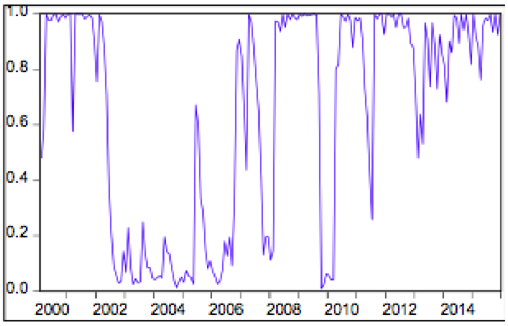
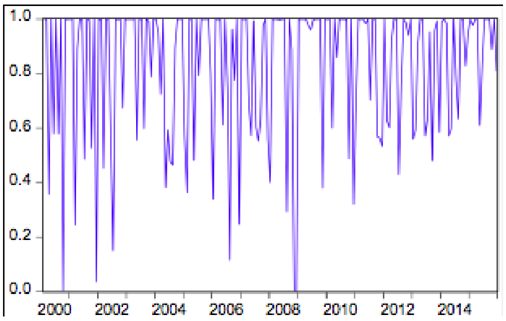


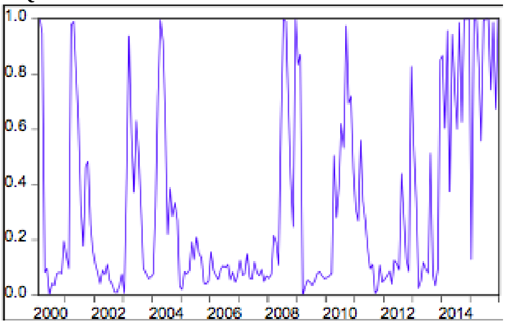
EOG Resources



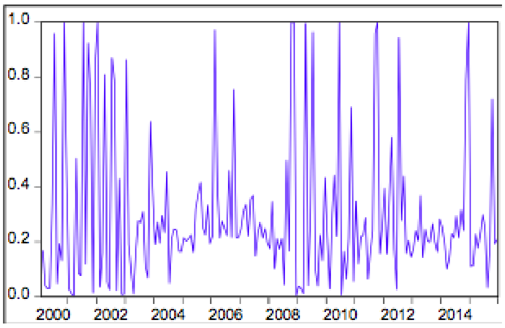
EQT



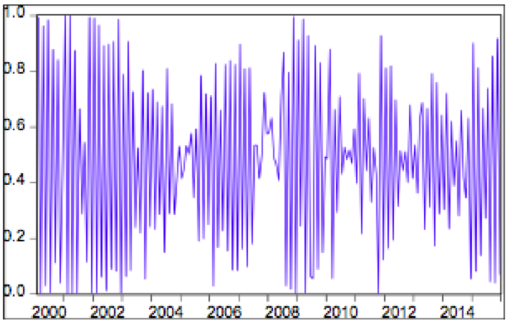
Exxon Mobile



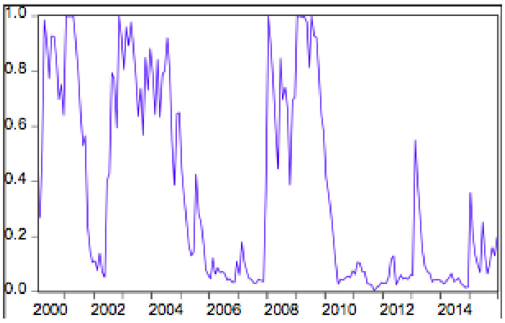
Goodrich Ptl.



Halliburton



Helmerich and Payne



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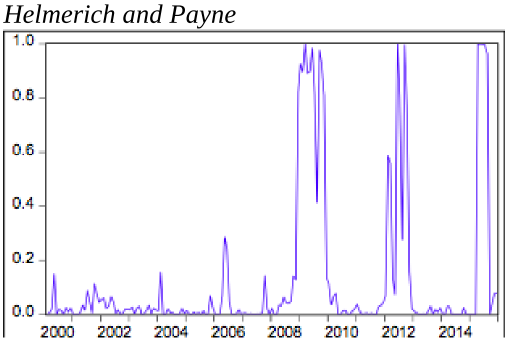
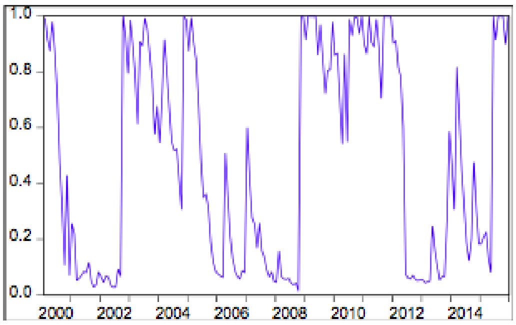
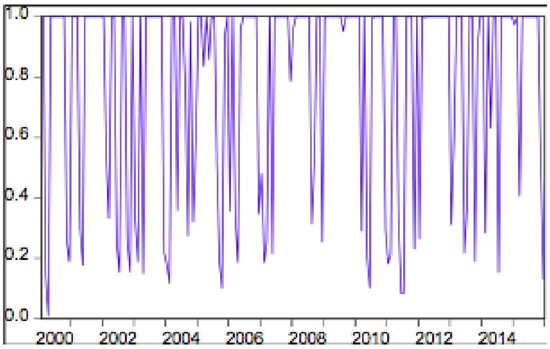


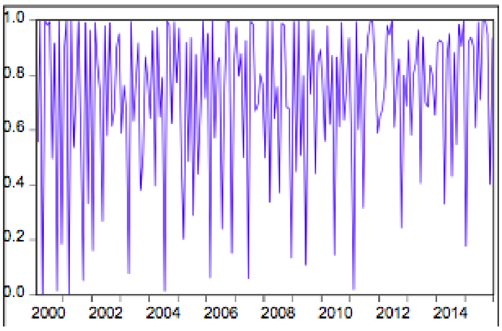
Hugoton Royalty Tst.



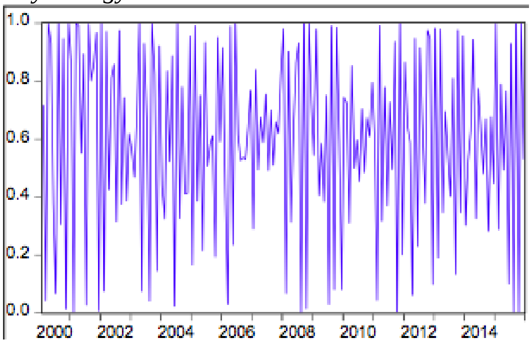
ION Geo.



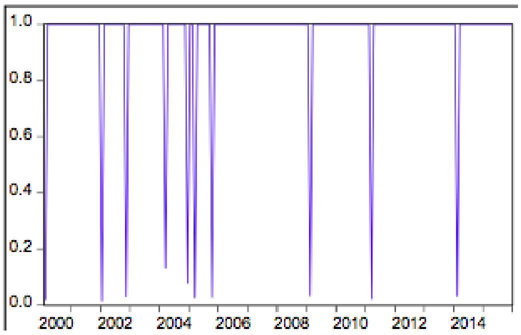
Key Energy



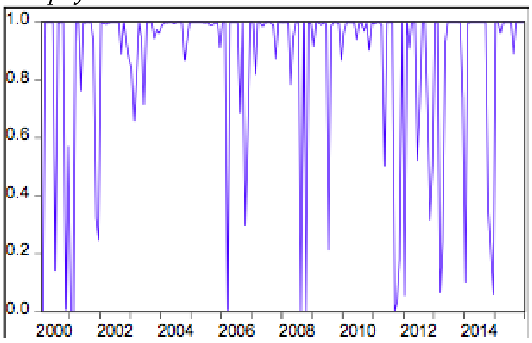
Mararthon Oil



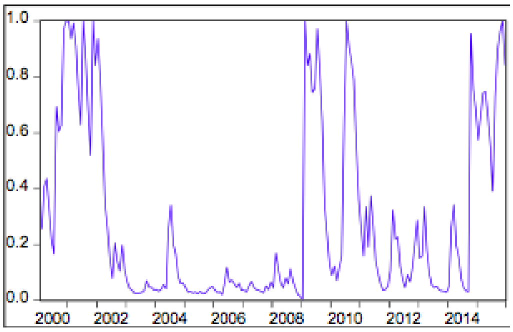
Murphy Oil



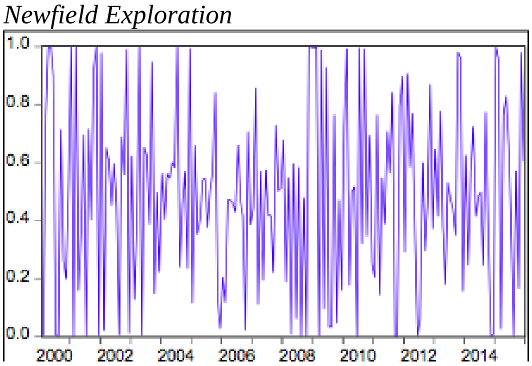
Nabors Industries



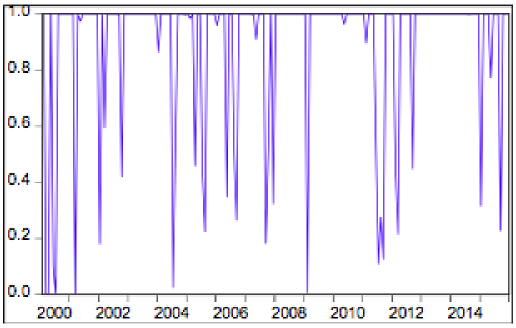
Newfield Exploration



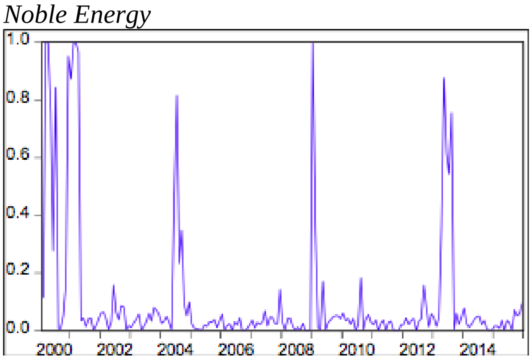
Noble Corporation



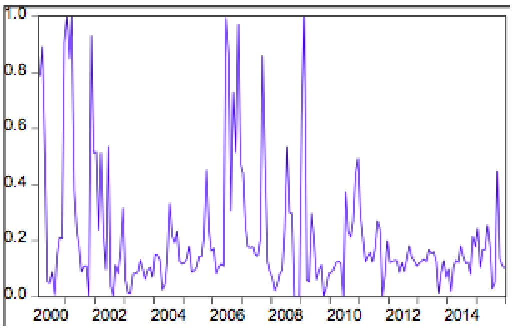
Noble Energy



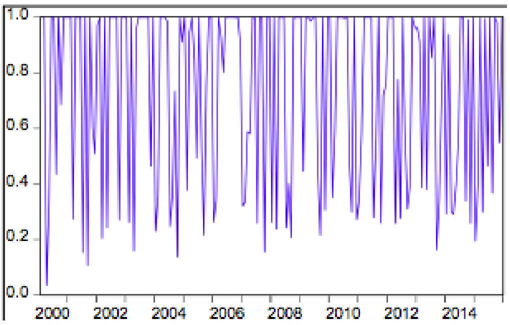
National Oilwell Varco



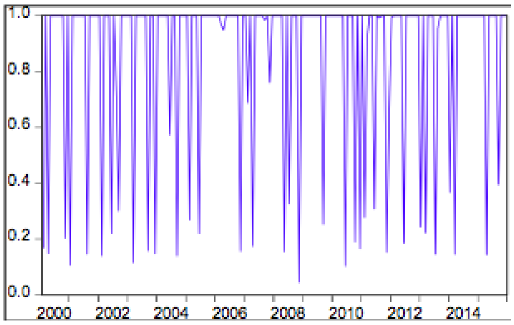
Occidental Ptl.



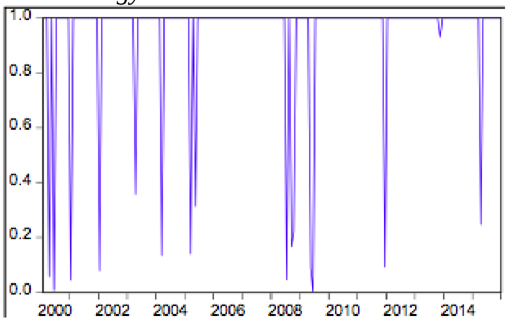
Oceaneering



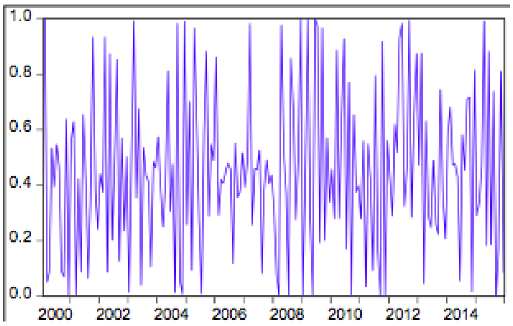
OGE Energy



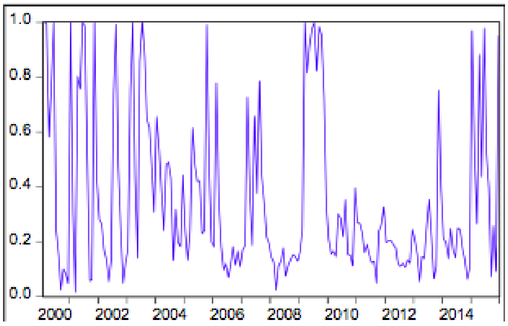
Panhandle Oil and Gas



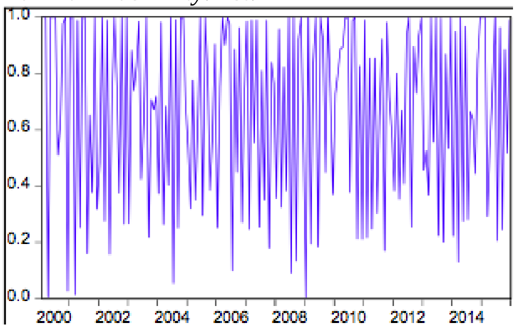
Parker Drilling



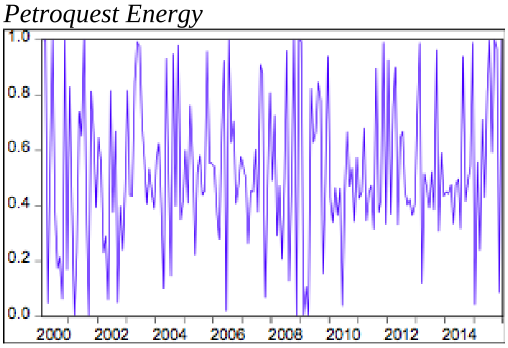
Permian Basin Rty. Tst.



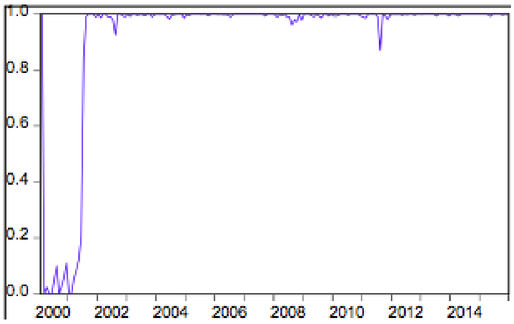
Petroquest Energy



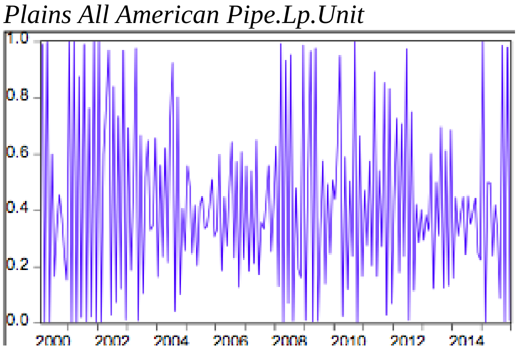
Pioneer Ntrl. Res.



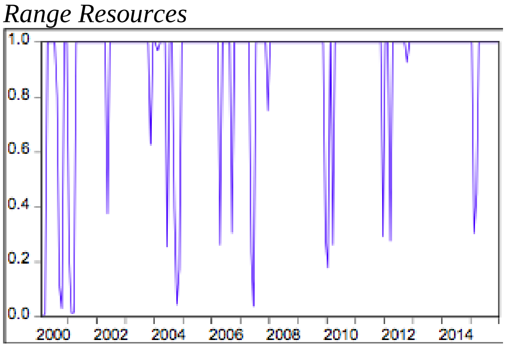
Plains All American Pipe.Lp.Unit



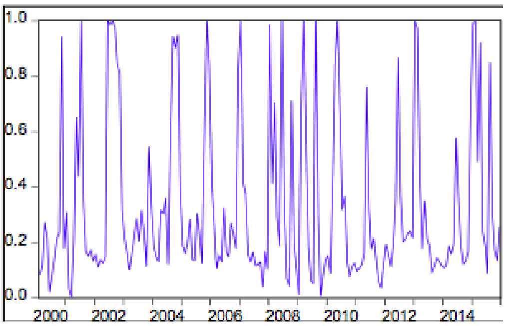
Range Resources



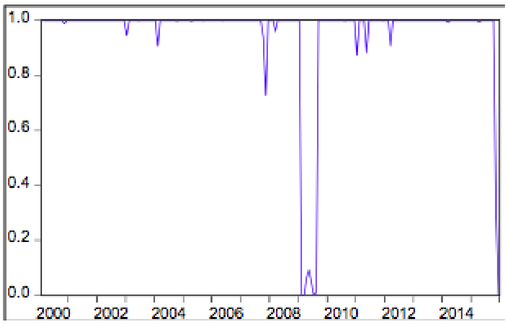
Rowan Com



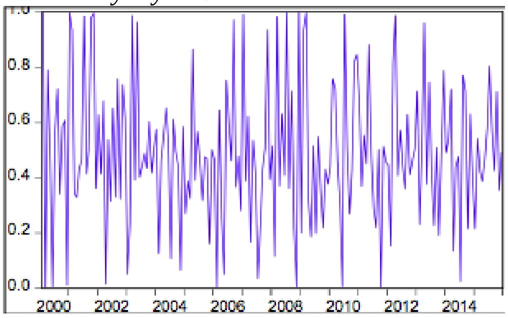
RPC



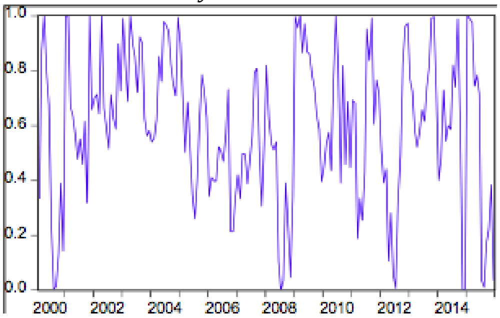
Sabine Royalty Tst.



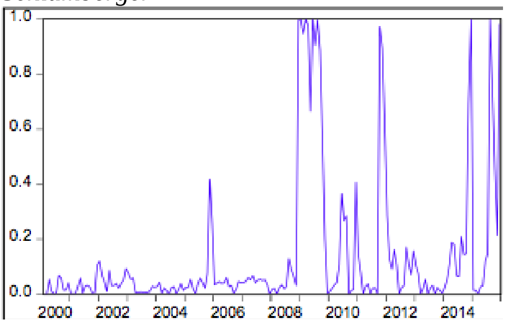
San Juan Basin Rty.Tst.



Schlumberger



SM Energy



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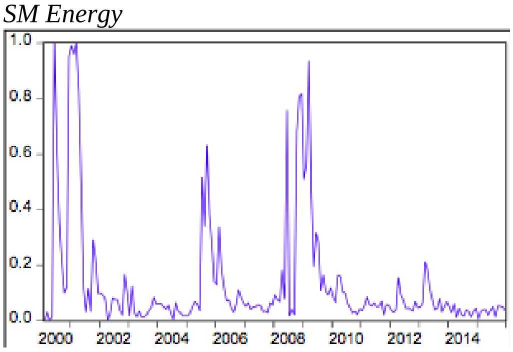

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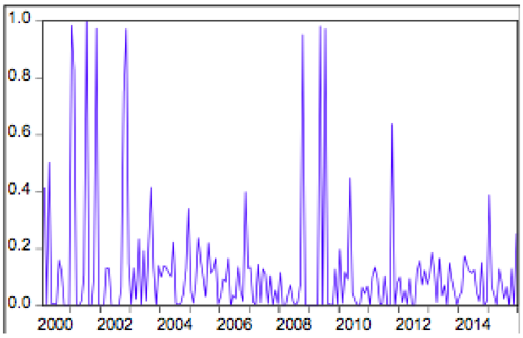
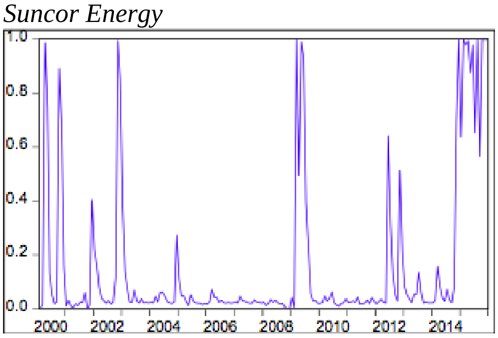
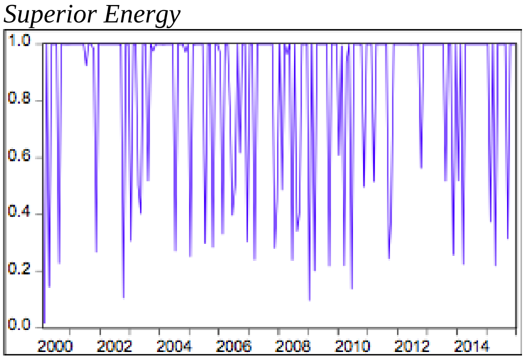


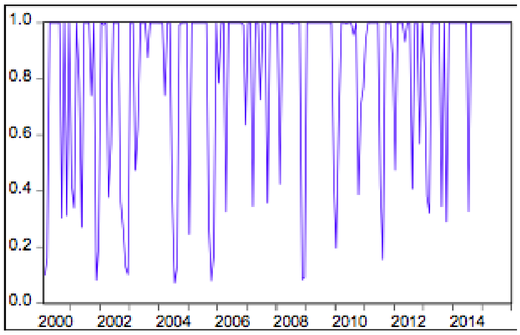
Superior Energy



Swift Energy



TC Pipelines



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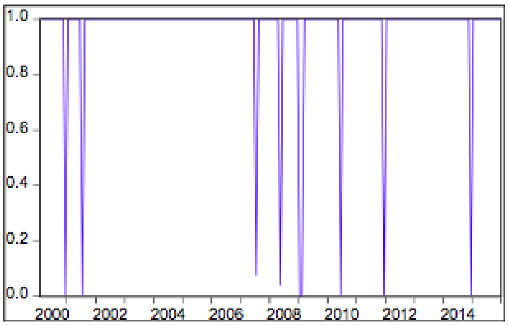
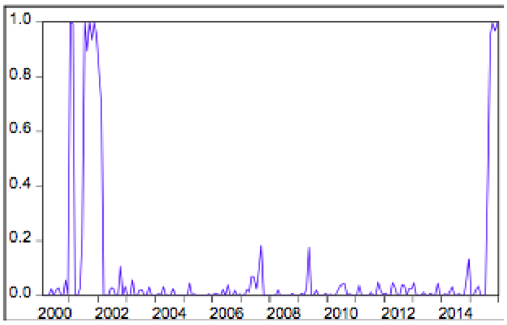
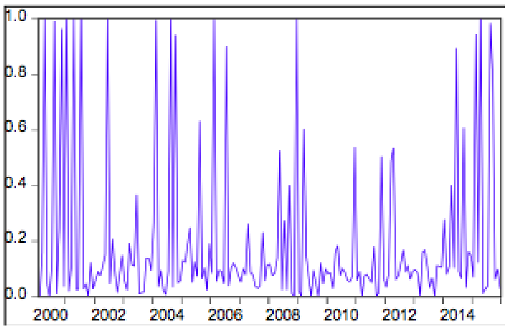


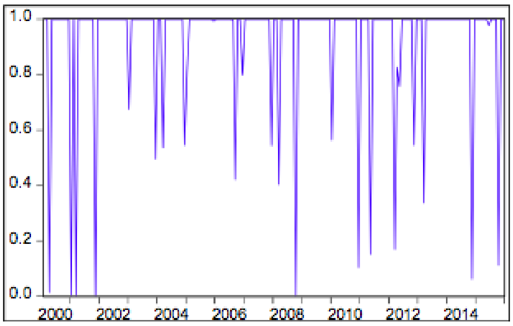
Transocean



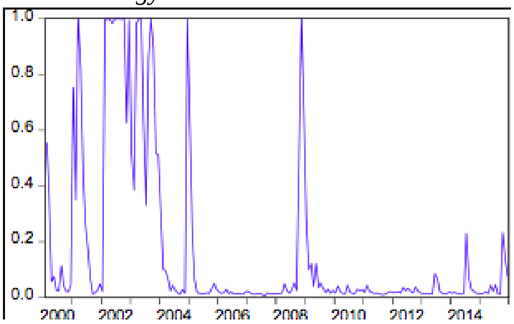
Unit



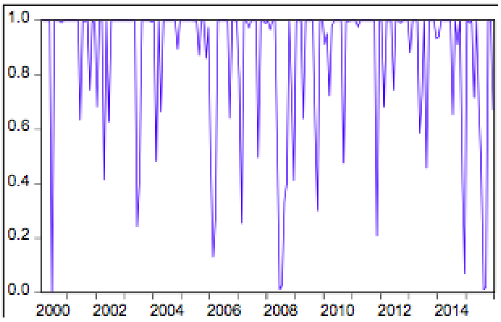
Vaalco Energy



Weatherford



Williams



Williams, Clayton