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Valuation of proved vs. probable oil and gas reserves

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Abstract: Oil and gas reserves are the most important assets of oil and gas companies. A source of confusion for investors in oil companies, is that reserves quantities and values are uncertain estimates. Reserves are typically classified according to probabilities of recovery from underground reservoirs. All US-listed companies are required to disclose proved reserves but not probable reserves, thus leaving out potentially important information for investors and financial analysts. This study addresses the impact on market valuation of various classifications of reserves amounts. Using a data sample of 94 companies that do disclose information on probable reserves, we compare the relation between three classifications of reserves and oil company returns. While we find that information on probable reserves do not have an impact on stock returns measured over the entire time period, this is not the case since 2009, coinciding with the onset of the shale gas revolution.

Subjects: Energy & Fuels; Mining, Mineral & Petroleum Engineering; Corporate Finance; Financial Accounting; Financial Statement Analysis

Keywords: oil and gas reserves; proved reserves; probable reserves; value relevance; oil company valuation; stock returns; valuation; Shell; Exxon; Chevron

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PUBLIC INTEREST STATEMENT

This paper investigates the relationship between oil and gas reserves and market valuation of oil and gas companies, a topic that is of interest to investors and analysts. It is well known that financial markets can react considerably to substantial changes in oil and gas companies' reserves. Oil and gas reserves are typically classified according to probabilities of recovery from underground reservoirs, such as proved (highest), probable and possible (lowest) reserves. The US Securities and Exchange Commission require that oil and gas companies only disclose one of these, proved reserves. We conjecture that information on also other reserves measures, such as probable and possible oil and gas reserves, could have an impact on oil company stock returns. Our results suggest that proved developed reserves are the main type of reserves used by investors to forecast future cash flows. However, we find that investors react differently to changes in probable oil and gas reserves, and especially after 2009, coinciding with the shale gas revolution.

1. Introduction

This paper investigates the relationship between oil and gas reserves and market valuation of oil and gas companies. This is a topic that concerns both investors and analysts. Financial markets can react considerably to substantial changes in oil and gas companies' reserves. For instance, the discovery of the large Johan Sverdrup field on the Norwegian continental shelf in 2011 led to a 30% appreciation in Lundin's share price on the day it was announced. Recently, Scholtens and Wagenaar (2011), find that the revisions of energy reserves significantly impact market values of oil and gas firms.

Although oil and gas reserves are the most important assets for oil and gas companies,[1] it can be quite challenging for analysts and investors to value the booked reserves that the companies disclose. As Osmundsen (2010) points out, the information value of booked reserves (proved reserves) suffers from a number of weaknesses. First, reserves are recognized as a function of average oil and gas price levels during the year.[2] Second, booked reserves are affected by contractual issues.[3] Finally, the most commonly referred to type of reserves, namely proved reserves, do not contain complete information on the future growth of the company since the proved reserves concept excludes less mature reserves. The Society of Petroleum Engineers (SPE, 2011) classifies reserves into three groups based on the uncertainty associated with their recoverability; proved, probable, and possible oil and gas reserves.[4] While oil companies calculate internal estimates for all three reserves types, they are only required to disclose one of these, proved reserves, to the financial markets. Thus, vital information relating to oil and gas assets, which investors and financial analysts require to forecast future cash flows, are not disclosed to the market place. The result is a systematic understatement of the true resource base for oil companies. However, in some countries, such as Canada, disclosures of proved and probable reserves are mandatory (Canadian Securities Administrators, 2002a, 2002b). Moreover, the legislation also permits the disclosure of contingent reserves. During 2008–2010, the U.S. Securities and Exchange Commission (SEC) and FASB (FASB) updated US disclosure rules allowing for disclosure of less mature reserves (FASB, 2009, 2010; SEC, 2008). Furthermore, several private consultancies such as Wood Mackenzie gather information on oil and gas fields for oil and gas companies and provide their own estimate of reserves, including reserve categorizations other than proved reserves. Hence, information on probable reserves is available to investors for a fee, suggesting that market valuations of oil and gas companies can be affected by information on probable reserves held by a part of the investor community. However, our knowledge of the impact of less mature reserves on market valuation is limited. Studies on the impact of changes in reserves on shareholder returns use either proved reserves amounts (Boyer & Filion, 2007; Clinch & Magliolo, 1992; Misund, 2015a; Misund, Asche, & Osmundsen, 2008; Misund, Osmundsen, & Sikveland, 2015; Spear, 1994) or proved reserves values (Alciatore, 1993; Bryant, 2003; Doran, Collins, & Dhaliwal, 1988; Spear, 1996; Teall, 1992). Very few studies focus on the relative importance of different types of reserves classifications or reserve maturity. The aim of our study is to fill this knowledge gap and examine the impact of changes in different types of reserves classifications on oil company valuation. Although this topic has not been addressed rigorously in the academic literature, circumstantial evidence suggests that investors evaluate probable and proved reserves differently. In 2004, the oil major Royal Dutch Shell disclosed a re-classification of 28% of their oil and gas reserves, from proved to probable reserves, an announcement which had a significant negative impact on their share price.

To test the research question of how changes in different types of oil and gas reserves relates to returns to shareholders, we regress total shareholder returns on different reserves classifications and a set of control variables such as profitability, market and extra market risks, and commodity price changes. We collect three types of reserves classifications that are associated with different probabilities of recoverability; proved developed, proved undeveloped, and probable. Proved developed reserves are the most mature and are associated with the highest probability of recovering the underground reserves, while probable reserves are associated with the lowest recoverability probability. Although recent updates in US regulation allows US-listed oil and gas firms to disclose probable reserves (FASB, 2010; SEC, 2008), few actually do. We have therefore collected data for a sample of non-US firms which provide information on probable reserve estimates. Our sample consists of 94 Canadian and International oil companies, for the years 1993–2013 (455 firm years).

We address an additional research question. Recently, Misund (2015a) found that the relationship between returns and proved reserves varied across energy type (gas vs. oil), and that there had been a structural shift post-2008, coinciding with the onset of the shale gas revolution in North America. The shale gas revolution is by many commentators considered a game changer. As a sensitivity analysis, we examine how this event has affected the relative impact of different reserves classifications on returns. The expectation is that only gas reserves have changed their impact on total shareholder returns since the shale gas revolution resulted in a sustained lower level of natural gas prices in North America.

We find a significant positive relation between changes in proved developed reserves and oil company returns. The evidence for less mature reserves, however, is unconvincing. Proved undeveloped reserves are only significant at the 10% level. Moreover, we are unable to uncover a significant association between oil company returns and probable reserves. This suggests that investors view changes in less mature oil and reserves as very uncertain, and they are unable to efficiently price this type of assets. The picture seems to be different when considering structural events such as the shale gas revolution, and taking into account hydrocarbon type (oil vs. gas). We find that the impact of the shale gas revolution has significantly affected the relationship between returns and gas reserves, but not with changes in oil reserves.

The results from our study improves our understanding of how different types of reserves impact oil company returns. In particular, we are able to identify the differential impact of different reserves classifications. Moreover, the results also suggest that an important defining event in the industry, exemplified by the shale gas revolution, can lead to structural breaks in the valuation of reserves. This result is relevant for evaluating the valuation of oil reserves in the current oil market downturn.

The remainder of the paper is organized as follows. Section 2 provides background information on oil and gas reserves in terms of reserves classification practices, disclosure rules, and accounting standards, and a review on the literature on the association between reserves and oil company shareholder returns. Section 3 describes the methodology and develops the hypotheses. Thereafter, Section 4 describes the data, followed by Section 5 presenting and discussing the empirical results. Section 6 concludes.

2. Background and literature

2.1. Oil and gas reserves

The companies' petroleum resources in underground reservoirs cannot fully be counted as an asset. Only the recoverable amounts can be monetized to future cash flows and therefore considered as inventory. The recoverability of reserves is a function of several variables including feasible technology, geology, and economics, and is associated with uncertainty.[5] In fact, the SPE classifies reserves into several groups according to both the uncertainty and maturity of the recoverable volumes (Figure 1).

The total recoverable volumes are not certain, but rather estimate of future production under certain conditions (Mitchell, 2004). These conditions include economic conditions such as commodity prices, knowledge of the projects' ability in development completion and extracting the resources, as well as geological information. Recently, both Exxon and Chevron downward revised their reserves amounts due to the low oil prices. Furthermore, the above-mentioned conditions are not always well defined. Since the estimation of reserve amounts cannot be done with complete objectivity, it is possible to arrive at different estimates for the same field. An example of this is Shell's 28% re-classification of their proved to probable reserves in 2004.

framework

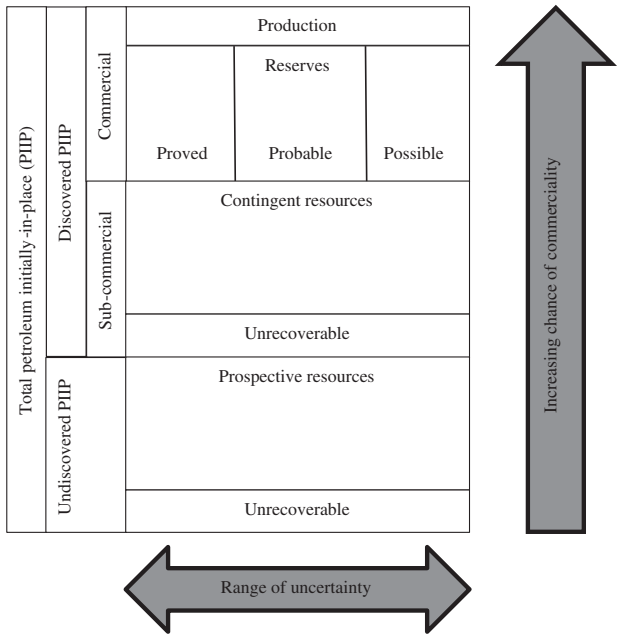

Figure 1. Society of Petroleum Engineers' oil and gas reserves classification framework.

Source: Society of Petroleum Engineers (2011).

2.2. Disclosure of oil and gas reserves

While oil companies have calculated their quantities of recoverable reserves for many decades, it was only in the late 1970s and early 1980s that they were actually required to disclose these amounts to the financial markets. The SEC defined the rules for disclosing oil and gas reserves values in a series of accounting series releases (ASR) (SEC, 1978, 1979, 1981). In the first two ASR's No. 253 and No. 269, the SEC proposed a new accounting method called Reserve Recognition Accounting (RRA). Unlike previously where the only reserve estimate available in the financial accounts were based on historical incurred cost, the RRA values were based on estimated future cash flows. In 1981, the SEC released ASR No. 289, where it concluded that RRA contained sufficient problems which prevented its use as a potential accounting method for oil and gas producers. Instead, the SEC indicated its support for the work undertaken by the FASB's project to develop a comprehensive package of reserves-based disclosures. This project culminated with the FASB SFAS No. 69 (SFAS No. 69) in 1982 (FASB, 1982), which to this day has sets the overall framework for the disclosure rules for oil and gas companies listed on US stock exchanges. The SFAS No. 69 was recently superseded by Accounting Standard Codification (ASC) Topic 132 (FASB, 2009, 2010). The ASC Topic 932 requires oil and gas producers to report several supplemental reserves measures.[6] First, oil and gas producers need to disclose the amounts of reserves they hold across types of products such as oil, gas and non-conventional resources, and across geographical locations. In addition, they need to disclose an estimate of the net present value of their proved reserves at fiscal year-end, called the standardized measure. Finally, they need to separately disclose the change in the standardized measure over the fiscal year. Nevertheless, in terms of types of reserves classes, oil and gas companies are only required to disclose proved reserves. While Topic 932 allows oil and gas producers to disclose probable reserves, most companies do not, making it difficult for investors to access this information. However, under Canadian rules, Canadian oil and gas companies are required to disclose both proved and probable reserves amounts, which allows for analysis into the relationship between different reserves classification and market valuation. We therefore use data from mainly Canadian companies to examine the relevance of different classification of reserves on the valuation and returns on oil companies' shares.

2.3. Previous studies on the importance of oil and gas reserves for investors

Several studies have examined the association between reserves and security returns in the first years following the release of the new regulation in the late 1970s and early 1980s. Some of the earliest studies address the impact of the now discontinued RRA measure and returns (Basu & Lynn, 1984; Dharan, 1984; Ghicas & Pastena, 1989; Magliolo, 1986). Other studies address the information content of the supplementary information oil and gas companies are required to disclose. This strand of the literature examines the relationship between market returns and disclosure of changes in both reserves amounts (Clinch & Magliolo, 1992; Harris & Ohlson, 1987; Spear, 1994) and reserves values (Alciatore, 1993; Doran et al., 1988; Kennedy & Hyon, 1992; Spear, 1996).[7] However, the results are mixed. Harris and Ohlson (1987) and Doran et al. (1988) found no support for the impact of changes in reserve values on security returns. Later studies suggest that separation of reserves into its individual components drastically improved the information content of the standardized measure (Alciatore, 1993; Spear, 1996). Furthermore, Boone (2002) argues that the apparent lack of a significant relationship between reserve value changes and security returns can be due to model misspecification (e.g. omitted variable bias).

A few studies have also examined the association of reserve quantities with oil company returns. Clinch and Magliolo (1992) found that changes in reserves due to production dominated all other reserve information. Moreover, Spear (1994) found that the individual components of reserve amounts changes (such as discoveries, production, purchases) improved the relationship with returns. Contrary to Clinch and Magliolo (1992), Spear (1994) and later Cormier and Magnan (2002), find that discoveries are more important than production. In fact, a recent study finds a negative relationship between changes in production and returns (Boyer & Filion, 2007). Furthermore, Osmundsen, Asche, Misund, and Mohn (2006), Osmundsen, Misund, and Asche (2007) and Quirin, Berry, and O'Bryan (2000) fail to find a significant relationship between market valuation ratios and the reserves replacement ratio, which is calculated as the ratio of new reserve additions divided by production. Hence, the empirical literature has not uncovered a robust relationship between reserves changes and market valuations.

Perhaps as a result of the focus on proved reserves by the regulators and the accounting standard setters, coupled with the lack of information released by oil companies, very few studies have addressed the relevance of different resource classifications. The aim of our paper is provide insight into the impact on less mature reserves on security returns.

3. Methodology

3.1. Theoretical and empirical modeling of the relationship between reserves and stock returns

Stock price returns can be affected by a multitude of factors, including profitability and systematic risk factors. Returns may also be influenced by elements specific to the industry to which the companies belong. For instance, oil and gas company returns may be affected by changes in the prices of oil and gas through the impact on revenues, changes in reserves as a result of successful exploration activities. The empirical literature investigating the determinants of stock returns broadly follow two threads. The first examines stock returns in the framework of standard asset prices models, such as the capital asset pricing model (CAPM) (Lintner, 1965; Mossin, 1966; Sharpe, 1964) or multifactor models such as the Fama–French–Carhart four factor model (Carhart, 1997; Fama & French, 1993, 1996). The limitation of this approach is that key elements such as profitability or other risk factors such as the oil price are not directly captured by standard asset pricing models.

To incorporate company profitability measures, industry-specific information or commodity price risk factors, the empirical literature suggest an alternative approach, such as the multifactor model applied by Sadorsky (2001) and Boyer and Filion (2007). This latter approach uses the standard market model as a starting point and includes additional risk factors which are believed to affect stock prices. The foundation for the additional variables is not necessarily dictated by theoretical models.

By contrast, our approach is to use a theoretical model for the relationship between stock returns and profitability. We use Ohlson's (1995) theoretical framework relating stock returns to profitability, both current and proxies for future profitability, in addition to the cost of capital. The Ohlson model is derived from, and therefore consistent with, the dividend discount model. The benefit of using the Ohlson model is that we can incorporate fundamentals such as profitability into the empirical model. Recent studies, such as Bhaskaran and Sukumaran (2016), and Asche and Misund (2016), highlight the importance of financial performance on the valuation of oil and gas companies.

Using the Ohlson model as a starting point, we include additional risk factors identified in other studies such as the Fama–French risk factors as well as changes in oil and gas prices. In this way, our empirical models build on both the previous works on asset pricing models, as well as the time series work by Sadorsky (2001) and others. We also include a measure of oil and gas reserves since this is the focus of our study. We use the following empirical representation of the Ohlson model:

$$r_{it} - RF_t = \theta_0 + \alpha_1 E_{it}/p_{it-1} + \alpha_2 \Delta E_{it}/p_{it-1} + \beta_1 \mathrm{MRP}_t + \beta_2 \mathrm{SMB}_t + \beta_3 \mathrm{HML}_t + \beta_4 \mathrm{MOM}_t + \beta_5 \Delta \mathrm{OP}_t + \beta_6 \Delta \mathrm{GP}_t + \delta \mathrm{OGR}_{it} + \varepsilon_{it} \quad (1)$$

where r_{it} is the total shareholder return for company i at time t. The profitability and shocks in profitability from $t-1$ to t, are captured by E_{it} and ΔE_{it}, respectively. The market risk premium (CAPM) is represented by MRP_t, while SMB_t and HML_t are the returns on the Fama–French (1993, 1996) Small-minus-big and high-minus-low factors, respectively. The Carhart (1997) momentum factor is denoted by MOM_t. We also include a set of commodity risk factors, $\Delta \mathrm{OP}_t$ and $\Delta \mathrm{GP}_t$, representing changes in oil and gas prices, respectively. RF_t is the risk free rate at time t, and ε_{it} is the error term.

The last variable, OGR, denotes a vector of oil and gas reserves variables. Ideally, we would like to compare proved to probable and possible reserves. However, we need to select among the types of reserves that are readily available for investors. Since possible reserves are not disclosed, we therefore select the following three types of reserves; proved developed, proved undeveloped and probable reserves. There is a distinction between proved developed and proved undeveloped. The former are reserves which can be extracted from existing wells, while the latter are classified as reserves from new wells on undrilled acreage or existing wells where a relatively major expenditure is required for completion. We expect that the market will distinguish between the two types of proved reserves, and together with probable reserves the model will provide insight into the relationship between different reserves types and oil company shareholder returns. This resulting model, which examines the relationship between stock returns and the three types of reserves classification, is referred to as "the total reserves model." We propose the following null hypotheses:

H_0^1: The coefficients on proved developed and proved undeveloped reserves are equal. Formally, this is a F-test of coefficient equality, $\delta_{\mathrm{provdev}} - \delta_{\mathrm{provundev}} = 0$. If the null hypothesis is rejected then the results provide evidence that investors value proved developed reserves differently than proved undeveloped reserves.

H_0^2: The coefficients on proved developed and probable reserves are equal. Formally, this is a F-test of coefficient equality, $\delta_{\mathrm{provdev}} - \delta_{\mathrm{prob}} = 0$. If the null hypothesis is rejected then the results provide evidence that investors value proved developed reserves differently than probable reserves.

H_0^3: The coefficients on proved undeveloped and probable reserves are equal. Formally, this is a F-test of coefficient equality, $\delta_{\mathrm{provundev}} - \delta_{\mathrm{prob}} = 0$. If the null hypothesis is rejected then the results provide evidence that investors value proved undeveloped reserves differently than probable reserves.

Despite our best efforts, the empirical model may still be misspecified. For instance, if we incorrectly fail to include one or more important explanatory variables in the empirical model, this can result in the "omitted variables bias," which is where the regression estimator becomes biased and

inconsistent. To mitigate the adverse affects of the omitted variables bias, we apply panel data techniques. Specifically, we use a fixed effects model.

3.2. Sensitivity analysis: The impact of the shale gas revolution

While the previous section addresses the differential impact of oil versus gas reserves on oil company returns, this relationship might not be constant over time. Certain aspects might affect the relationship between changes in reserves and returns. In fact, early studies found a negative effect of investment in exploration activities on security returns. McConnell and Muscarella (1985), Picchi (1985) and Jensen (1986, 1988) examined the impact on valuation of investments in exploration and development (E&D) activities during a time period characterized by declining commodity prices, excessive spending on E&D and excessive levels of reserves. The results suggested that the market reacted negatively to E&D spending. An analogy can be found in recent years. During the late ,2000s, a structural change in the US natural gas market occurred in the form of a shale gas boom that has increased domestic natural gas production to the degree that only minimal LNG imports might be required to meet domestic demand in the future. After George P. Michell's pioneering work for one-and-a-half decade, the use of hydraulic fracking had a commercial breakthrough in the late 1990s in the Barnet Shale. Devon Energy took this breakthrough further when they combined the use of hydraulic fracking with horizontal drilling in 2003 (Yergin, 2011). This combined development allowed the recovery of shale gas at significantly reduced costs. This has led to an influx of so-called unconventional gas on the domestic market. In lack of sufficient export capacity this additional supply has depressed US natural gas prices substantially relative to pre shale gas levels. The so-called "shale revolution" is commonly dated to around 2009 (see e.g. Oglend, Lindbäck, & Osmundsen, 2016), mostly for natural gas, but also for oil at a later stage, and may have impacted on the importance of gas reserves. The onset of the shale gas revolution has coincided with a substantial drop in gas prices, while oil prices have increased.[8] Erdōs (2012), using a vector error correction model, dates the decoupling of oil and gas prices to 2009, the same year as the onset of the shale gas revolution. Although the shale gas revolution happened mostly in the US, it has also affected the revenue of Canadian oil and gas companies in our sample. Directly, as Canadian oil and gas companies own assets in the US shale gas play, and indirectly though the fact that the Canadian and the US markets for natural gas are integrated, see Bachmeier and Griffin (2006). Hence, an interesting research question emerges: has there been a structural shift in the relationship between oil company shareholder returns and gas reserves in 2009? If there has been a differential impact from gas or oil reserve changes on returns, then it is possible to examine this using a structural shift methodology.

Following Misund et al. (2008) and Misund (2015a), we apply the Gujarati's (1970a, 1970b) version of the Chow test (Chow, 1960). We include a dummy variable that takes the value 1 for observations in the year 2009 onward, and 0 otherwise. The dummy variable is interacted with the changes in reserves variables, OGR × YR2009, and formally tests for a structural shift using a Wald test on the coefficients on the interaction terms, both for gas and oil reserves. The hypotheses can be formulated as follows:

H_0^4: No structural shift in the coefficients of the interaction terms between a shale gas dummy variable and gas reserves.

H_0^5: No structural shift in the coefficients of the interaction terms between shale gas dummy variable and oil reserves.

If we fail to reject H_0^4 and reject H_0^5, this provides evidence that the coefficient on gas reserves has changed, but not that of oil reserves. This will provide evidence that there has been a change in the gas reserves–returns relationship coinciding with the onset of the shale gas revolution. In order to be able to differentiate between the impacts relating to gas or oil reserves, we do the analysis in two

steps. We estimate Equation (1) with total reserves disaggregated in to both gas and oil proved developed, proved undeveloped and probable reserves. For ease of presentation to readers, we apply a stepwise approach. The dummy variable is interacted only with the gas reserves variables in the first step, and only with oil reserves variables in the second step. These two models are referred to as "Shale gas model: gas" and "Shale gas model: oil," respectively.

4. Data

4.1. Data sources and descriptive statistics

We collect data from the IHS Herold database (www.ihs.com/herold). This database contains financial and operational data for more than 800 energy companies. From this universe, we select those companies that have data on both proved developed, proved undeveloped and probable reserves. This gives us a total of 94 Canadian and international oil and gas companies. We use annual data for the years 1993–2013, resulting in 455 firm year observations.

We collect three types of reserves; proved developed, proved undeveloped and probable reserves both oil and gas reserves. The following definitions are taken from Exxon Mobil's 2013 10-K filing supplemental information on oil and gas exploration and production activities and SPE (1997):

SPE (1997) defines "Proved oil and gas reserves" as "those quantities of oil and gas, which, by analysis of geoscience and engineering data, can be estimated with reasonable certainty to be economically recoverable, from a given date forward, from known reservoirs, and under current economic conditions, operating methods and government regulations. Proved reserves can be categorized as developed or undeveloped."

Exxon Mobil Annual Report 2013 defines "Proved developed reserves" as "those volumes that are expected to be recovered through existing wells with existing equipment and operating methods or in which the cost of the required equipment is relatively minor compared to the cost of a new well."

Exxon Mobil (2013) defines "Proved undeveloped reserves" as "those volumes that are expected to be recovered from new wells on undrilled acreage, or from existing wells where a relatively major expenditure is required for recompletion."

SPE (1997) defines "Probable oil and gas reserves" as those unproven reserves which analysis of geological and engineering data suggest are more likely than not to be recoverable. In this context, when probabilistic methods are used, there should be at least a 50% probability that the quantities actually recovered will equal or exceed the sum of estimated proved plus probable reserves.

The total shareholder returns are calculated over the fiscal year and are the sum of capital gains and dividend yields. The annual risk-free rates and annual equity risk factors are taken from Ken French's database. The commodity price risk factors are calculated as the return over the fiscal year of the front month West Texas intermediate crude oil futures and Henry Hub natural gas futures contracts, listed at the New York Mercantile Exchange.

Table 1 provides descriptive statistics for the sample. All classifications of reserves have on average been growing over the time period examined in our analysis. The data also show that gas reserves seem to have grown more than oil reserves for the companies in the sample. Furthermore, the increase in proved developed reserves has been 8.1% annually, compared to 6.0 and 1.3% for proved undeveloped and probable reserves, respectively. The average profitability has been positive, but very volatile. The data also show that the oil and gas prices have increased over the time period studied, even despite the gas price fall since 2008.

Table 1. Sample description

Variable	Mean	St. dev	25 percentile	Median	75 percentile
Returns	0.374	1.095	−0.132	0.158	0.548
E	0.019	0.293	<0.001	0.057	0.103
Δ*E*	0.029	0.415	−0.030	0.009	0.054
DEV	0.081	0.303	−0.018	<0.001	0.099
DEV GAS	0.252	1.202	−0.062	<0.001	0.268
DEV OIL	0.039	0.169	−0.007	<0.001	0.035
UNDEV	0.060	0.326	−0.011	<0.001	0.070
UNDEV GAS	0.157	0.801	−0.023	<0.001	0.163
UNDEV OIL	0.031	0.217	−0.002	<0.001	0.022
PROB	0.013	0.093	<0.001	<0.001	<0.001
PROB GAS	0.031	0.282	<0.001	<0.001	<0.001
PROB OIL	0.007	0.073	<0.001	<0.001	<0.001
MRP	0.081	0.194	0.008	0.107	0.202
SMB	0.033	0.120	−0.037	0.004	0.117
HML	0.025	0.161	−0.080	0.037	0.132
MOM	0.056	0.242	0.032	0.086	0.178
ΔOP	0.156	0.405	−0.071	0.082	0.405
ΔGP	0.206	0.793	−0.209	0.053	0.262

Notes: *E* = earnings after tax scaled by previous years market value of equity, ΔE = change in earnings after tax, scaled by previous years market value of equity. DEV = changes in total proved developed reserves, DEV GAS = changes in proved developed gas reserves and DEV OIL = changes in proved developed oil reserves. UNDEV = changes in total proved undeveloped reserves, UNDEV GAS = changes in proved undeveloped gas reserves and UNDEV OIL = changes in proved undeveloped oil reserves. PROB = changes in total probable reserves, PROB GAS = changes in probable gas reserves and PROB OIL = changes in probable oil reserves. The reserves variables are calculated as changes in reserves amounts divided by the beginning of year reserve amount. MRP = market risk premium, SMB and HML are the Fama–French (1993, 1996) small-minus-big and high-minus-low risk factors, respectively. MOM is the Carhart (1997) momentum risk factor. ΔOP and ΔGP are the percentage changes in oil and gas prices, respectively.

4.2. Diagnostics tests

We test the variables for stationarity using the augmented Dickey–Fuller test (Dickey & Fuller, 1979; Said & Dickey, 1984), and the residuals for heteroskedastiticy using the Breusch–Pagan test (Breusch & Pagan, 1979) and serial correlation using the Breusch–Godfrey/Wooldridge test (Breusch, 1978; Godfrey, 1978; Wooldridge, 2002). We reject the null hypotheses of unit roots for all variables at 2 lags (Table 2), meaning that the data are stationary and need not be first differenced. However, we find the presence of both heteroskedasticity and serial correlation in the error terms in both the (Table 3). We therefore use the Arellano (1987) method for adjusting the standard errors for both heteroskedasticity and serial correlation for fixed effects models.

Table 2. Unit root test

Variable	ADF test	*p*-value
Returns	−13.208	<0.001
E	−11.385	<0.001
Δ*E*	−14.576	<0.001
DEV	−11.498	<0.001
DEV GAS	−11.427	<0.001
DEV OIL	−10.469	<0.001
UNDEV	−10.697	<0.001
UNDEV GAS	−8.911	<0.001
UNDEV OIL	−11.992	<0.001
PROB	−10.419	<0.001
PROB GAS	−9.227	<0.001
PROB OIL	−10.893	<0.001
MRP	−13.373	<0.001
SMB	−15.258	<0.001
HML	−15.640	<0.001
MOM	−15.419	<0.001
ΔOP	−16.035	<0.001
ΔGP	−11.958	<0.001

Notes: The variables are tested for the presence of unit root using the augmented Dickey-Fuller test with a null hypothesis of a unit root (the alternative hypothesis is that the variables are stationary). E = earnings after tax scaled by previous years market value of equity, ΔE = change in earnings after tax, scaled by previous years market value of equity. DEV = changes in total proved developed reserves, DEV GAS = changes in proved developed gas reserves and DEV OIL = changes in proved developed oil reserves. UNDEV = changes in total proved undeveloped reserves, UNDEV GAS = changes in proved undeveloped gas reserves and UNDEV OIL = changes in proved undeveloped oil reserves. PROB = changes in total probable reserves, PROB GAS = changes in probable gas reserves and PROB OIL = changes in probable oil reserves. The reserves variables are calculated as changes in reserves amounts divided by the beginning of year reserve amount. MRP = market risk premium, SMB and HML are the Fama–French (1993, 1996) small-minus-big and high-minus-low risk factors, respectively. MOM is the Carhart (1997) momentum risk factor. ΔOP and ΔGP are the percentage changes in oil and gas prices, respectively.

Table 3. Tests for heteroscedasticity and serial correlation

	Heteroskedasticity	Serial correlation
Total reserves model	459.212***	11.268***
Shale gas model: Gas	810.989***	16.883***
Shale gas model: Oil	767.215***	11.410***

Notes: Heteroskedasticity is tested using the Breusch–Pagan test (H_0: homoskedasticity) and serial correlation is tested using Breusch–Godfrey/Wooldridge (H_0: no serial correlation). Values are BP-statistic (Breusch–Pagan), χ^2-statistic (Breusch–Godfrey/Wooldridge test).

***Statistical significance value is $p < 0.01$.

5. Results and discussion

5.1. The impact in shareholder returns of changes in proved developed, proved undeveloped, and probable reserves

In this section, we present the results from the empirical model in Equation (1) and hypotheses 1–3. The results show that several of the variables contribute to explaining the variation in total shareholder returns (Table 4). First, we find a significant impact of earnings on returns, but not from changes in earnings. This is not surprising since many studies have suggested that investors may have limited confidence in accounting earnings for oil and gas companies (Cormier & Magnan, 2002; FASB, 1982; Misund, 2015b; Misund & Osmundsen, 2015). An alternative explanation is that earnings volatility may affect the relevance of accounting earnings from investors (Misund, 2016). Second, we find that several of the common risk factors are priced by investors, notably, momentum (MOM), small-minus-big (SMB), and changes in oil and gas prices. This result highlights the importance of including a larger set of risk factors than is typically done in similar studies. Surprisingly, investors in the companies in our selection do not price the market risk premium. Possibly, this might be due to the sample consisting primarily of non-US securities, while the MRP risk factor is calculated from listed US firms. Interestingly, the loading on the MOM factor is significant and negative. This is indicative that mean reversion, and not momentum, explains part of the variation in oil company returns. This is possibly related to the mean reverting nature of commodities such as oil and gas prices (Pindyck, 2003, 2004). Third, we find that changes in proved reserves are positively associated with security returns at the 1% significance level. This is consistent with prior studies (e.g. Spear, 1996). Moreover, our results suggest that proved undeveloped reserves impact returns, but only at a 10% level, indicative of a much weaker link to valuation than for proved developed reserves. The coefficients on both proved developed and proved undeveloped are similar, which is also confirmed by the statistical tests on the parameters (Table 5). However, the results also suggest that probable

Table 4. Regression results

Variable	Coefficients
Intercept	0.040
E	0.277**
Δ*E*	0.106
Proved developed	0.435***
Proved undeveloped	0.403*
Probable	0.114
MRP	−0.149
SMB	2.281***
HML	0.170
MOM	−0.677*
ΔOP	0.732***
ΔGP	0.215***
Adjusted R^2	0.294
F-statistic	17.428***
N	455

Notes: E = earnings after tax scaled by previous years market value of equity, ΔE = change in earnings after tax, scaled by previous years market value of equity. DEV = changes in total proved developed reserves, UNDEV = changes in total proved undeveloped reserves, and PROB = changes in total probable reserves. The reserves variables are calculated as changes in reserves amounts divided by the beginning of year reserve amount. MRP = market risk premium, SMB and HML are the Fama–French (1993, 1996) small-minus-big and high-minus-low risk factors, respectively. MOM is the Carhart (1997) momentum risk factor. ΔOP and ΔGP are the percentage changes in oil and gas prices, respectively.

*Statistical significance value is $p < 0.10$.

**Statistical significance value is $p < 0.05$.

***Statistical significance value is $p < 0.01$.

Table 5. Hypothesis testing (H_0^1, H_0^2, and H_0^3)

	F	*p*-value
H_0^1: DEV = UNDEV	0.0122	0.9122
H_0^2: DEV = PROB	1.1223	0.2489
H_0^3: UNDEV = PROB	0.6657	0.4150

Note: DEV, UNDEV and PROB represent the coefficients on changes in developed, undeveloped, and probable reserves (total), respectively.

reserves do not impact returns of oil and gas companies. A possible explanation is that investors do not consider that information about this type of reserves conveys information that is useful to forecasting future cash flows. It seems that investors primarily use information on proved developed reserves to forecast futures cash flows and secondarily use proved undeveloped reserves.

The model in Equation (1) might be too simple, and may suffer from two shortcomings. First, the model does not differentiate between oil and gas reserves. Investors might place different values on gas versus oil reserves. Second, changes in the relationship between reserves and valuation over time as suggested by prior research (Jensen,1986, 1988; McConnell & Muscarella, 1985; Picchi, 1985; Spear, 1996). We conjecture that a major event such as the Shale gas revolution might have affected the relationship between reserves and returns. The impacts of oil versus gas reserves, and of structure events, are addressed in the next section.

5.2. The impact of Shale gas revolution on the reserve–return relation

In the following section, we examine the impact of the industry event surrounding the shale gas revolution. Many commentators have attributed the start of the shale gas revolution to year 2009, and this date serves as the break point in our analysis. In particular, we examine whether the coefficients on gas reserves have changed after 2009. The analysis is done in two steps. First, the shale gas dummy variables are interacted with only the gas reserve variables (Table 6, Column 2). Next, the analysis is repeated with an interaction between the dummy variables and only the oil reserve variables (Table 6, Column 3).

The results suggest that the relationship between gas reserves changes before and after the onset of the shale gas revolution. The coefficient on the developed gas reserves prior to 2009 is 0.182, and is significant at the 1% level. This is also the case for the interaction between the dummy variable for the shale gas revolution (which takes the value 1 for years 2009–2013, and 0 for the years 1993–2008), resulting in a parameter of −0.157 (0.182–0.339) for the post-shale gas period. This means that increases in proved developed gas reserves after 2008 have had a negative impact on oil and gas shareholder returns, *ceteris paribus*. A plausible explanation is that there was a substantial and prolonged fall in gas prices after the financial crisis, possibly to a level where the investors believe to be unprofitable. Investors might value gas reserves lower than earlier if they believe that the subdued prices will last for a substantial time period. Hence, expected future cash flows from the production of gas reserves appear to have dropped.[9] This explanation is consistent with findings from studies of oil reserves in the 1980s (Jensen, 1986, 1988; McConnell & Muscarella, 1985; Picchi, 1985).

A characteristic of shale gas reserves is that the technology allows a much more rapid development and production than conventional gas plays. This suggests that investors might be of the opinion that the lower cash flows come earlier when produced from shale gas formations, than from other conventional reserves, and hence are discounted less and have a larger impact on shareholder values. This may also explain why the coefficient on probable gas reserves post-2008 is not negative, but in fact positive and significant at the 5% level. The probable reserves are less mature, and can generate cash flows further into the future, possibly when the gas prices might be higher. Casual observations of the New York Mercantile Exchange forward curves for Henry Hub Natural gas futures contracts indicate that the curves seemed to be in contango during this time period, suggesting an expected increase in prices.[10]

Table 6. Oil vs. gas: structural shift due to shale gas

	Reserves classification	
Variable	**Gas**	**Oil**
Intercept	0.044	0.033
SHALE	−0.030	0.001
E	0.235***	0.251***
Δ*E*	0.120	0.062
DEV GAS	0.182***	−0.038
DEV GAS × SHALE	−0.339***	
DEV OIL	0.675***	0.725**
DEV OIL × SHALE		−0.186
UNDEV GAS	−0.017	−0.133*
UNDEV GAS × SHALE	−0.106	
UNDEV OIL	0.609	0.597
UNDEV OIL × SHALE		0.339
PROB GAS	−0.025	0.271
PROB GAS × SHALE	0.529**	
PROB OIL	−0.221	−0.469
PROB OIL × SHALE		0.482
MRP	−0.122	−0.050
SMB	2.465***	2.353***
HML	0.073	0.021
MOM	−0.668*	−0.710*
ΔOP	0.740***	0.686***
ΔGP	0.215***	0.218***
Adjusted R^2	0.338	0.317
F-statistic	13.223***	11.998***
Wald χ^2	11.984**	3.082
N	455	455

Notes: E = earnings after tax scaled by previous years market value of equity, ΔE = change in earnings after tax, scaled by previous years market value of equity. DEV GAS = changes in proved developed gas reserves and DEV OIL = changes in proved developed oil reserves. UNDEV GAS = changes in proved undeveloped gas reserves and UNDEV OIL = changes in proved undeveloped oil reserves. PROB GAS = changes in probable gas reserves and PROB OIL = changes in probable oil reserves. The reserves variables are calculated as changes in reserves amounts divided by the beginning of year reserve amount. MRP = market risk premium, SMB and HML are the Fama–French (1993, 1996) small-minus-big and high-minus-low risk factors, respectively. MOM is the Carhart (1997) momentum risk factor. ΔOP and ΔGP are the percentage changes in oil and gas prices, respectively. SHALE is a dummy variable that takes the value 1 if year is less than 2009, and 0 otherwise.

*Statistical significance value is $p < 0.10$.

**Statistical significance value is $p < 0.05$.

***Statistical significance value is $p < 0.01$.

Consistent with our expectations, the shale gas revolution has not impacted the oil reserves–returns relation. The results therefore suggest that only the relationship between returns and gas reserves have changed. Next, we formally test for a structural shift using Wald χ^2 tests. In line with expectations we found a structural shift in the relationship between market returns and changes in gas reserves (reject H_0^4), but not for the association with oil reserve changes (cannot reject H_0^5). We posited that if we could simultaneously reject H_0^4 but not reject H_0^5, this would provide evidence of that the shale gas revolution has impacted the relative reserves–returns relationship of gas versus oil reserves. Our results suggest that the shale gas revolution has impacted how investors value gas reserves.

6. Conclusion

This paper studies the relationship between total shareholder returns and three types of reserves classifications. Oil companies under US accounting rules and regulation are only required to disclose proved oil and gas reserves. This is also the reason why prior studies examining the impact of reserves on returns have focused on proved reserves. However, as suggested by Osmundsen (2010), a major weakness of the proved reserves concept is the exclusion of more immature reserves. In fact, the SPE classifies oil and gas reserve according to probability of recoverability from petroleum reservoirs. Hence, this information can provide information for investors wanting to forecast future cash flows. Since oil companies are not required to disclose it, the information is not readily available for investors. However, in some countries outside the US, disclosure of other reserves classifications is mandatory. Using a sample of firms, mainly Canadian, which disclose information on immature reserves, we address three issues. First, we examine if other reserves classifications other than proved developed reserves are valuation relevant. Second, we test if gas and oil reserves are valued differently across reserves classifications. Last, we test whether the impact of an industry event with wide ranging effects has impacted the reserves–returns relationship differently for oil and gas reserves, and across the three reserves classifications.

Our results suggest that proved developed reserves are the main type of reserves used by investors to forecast future cash flows. However, we do find that there is a difference between oil and gas reserves, and especially after 2009, coinciding with the shale gas revolution. The effect can be explained by the impact of shale gas on the natural gas prices in North America.

From late 2014 to mid-2015, the crude oil prices fell from above 100 USD/barrel to less than 50 USD/barrel. Many commentators suggested that the recent US onshore shale oil boom was the culprit, flooding the markets with oil. In many ways the shale oil boom resembles the shale gas boom, but the effects will only reveal themselves in the years to come. Our results can therefore also be relevant for understanding the recent shale oil boom, the resulting prolonged oil price slump, and the how it may have affected the valuation of oil and gas companies.

Our results also have some policy implications. For many years, geologists have been using a much wider definition of oil and gas reserves than the SEC has. The results suggest that information on probable reserves bears only a limited relevance for investors in Canadian and other non-US oil and gas firms. The attention to the amount of and changes in probable reserves by investors and analysts in general might improve if mandatory disclosure was introduced also by all oil and gas companies. This is especially the case for companies listed in the US, which is the primary capital market for oil and gas equities.

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Notes
1. Reserves in the US can also effect wealth of individuals owning oil and gas assets directly, not only through stock exchange listed companies (Fitzgerald & Rucker, 2016).
2. Under the Financial Accounting Standards Board's (FASB) Statement of Financial Accounting Standards (SFAS) No. 69 (FASB, 1982), the amount of reserves was estimated using oil and gas prices at the fiscal year-end; while under the current rules of FASB Accounting Standards Codification Topic 932 (FASB, 2010), the annual average of the monthly average oil and gas prices are used.
3. See also Bindemann (1999) and Kretzschmar, Misund, and Hatherly (2007) for a discussion on the impact of production sharing agreements on accounting disclosures.

4. SPE combines the reserves into 1P (proved), 2P (proved plus probable) and 3P (proved plus probable plus possible) and define probabilities of 90, 50, and 10% of final recovered reserves exceeding the 1P, 2P, and 3P amounts, respectively.
5. Reserve amounts can be increased by enhanced oil recovery techniques (EOR) (Sevin & Ortega, 2016).
6. Early on there were inconsistencies between the 1981 SPE and 1978 SEC definitions. This led to efforts to align the definitions which culminated in the 1997 SPE reserves definitions for proved, probable, and possible categories (Harrell & Gardner, 2005). While 1997 SPE and 1978 SEC proved reserves definitions are very similar, the SEC regulations were generally considered to be more restrictive. In 2008, the SEC rules were updated and are now consistent with SPE's (SEC, 2008).
7. A strand of the literature also examine the value relevance of reserve amounts and net present values, i.e. regression of market values on reserves in levels form (see e.g. Berry, Hasan, & O'Bryan, 1998; Bryant, 2003; Cormier & Magnan, 2002; Misund et al., 2008).
8. Academic studies have addressed the divergence of oil and gas prices during this period (see e.g. Asche, Oglend, & Osmundsen, 2012; Erdõs, 2012).
9. Shale gas economics is also affected by costs, including drilling costs, completion, and productivity (see Ikonnikova, Gülen, Browning, and Tinker (2015)) for a study on shale gas economics and the well level.
10. Assuming that the Rational Expectations Hypothesis holds.

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