Reserves Replacement and Oil and Gas Company Shareholder Returns

by

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Abstract

This paper examines how oil and gas companies' reserves growth affects their share price returns. In particular we examine three issues affecting the relation between reserves changes and oil and gas firm returns. First, we examine if investors value reserves replacement as a result of exploration activities differently to reserves growth through acquisitions. In the second analysis we test if reserves replacement of oil reserves impacts stock returns differently than changes in gas reserves do. Third, we examine the impact of the Shale gas revolution and the subsequent oil and gas price divergence on the association between returns and replacement of oil versus gas reserves. The results suggest that investors seem to be indifferent to reserves replacement strategy (exploration or acquisition). However, we find that changes in oil reserves impact oil and gas company returns differently than changes in gas reserves does. Moreover, we find that there has been a structural shift in the relation between returns and changes in gas reserves (but not changes in oil reserves) after 2008, coinciding with the Shale gas revolution and the break in the oil-gas price link. This latter result can be relevant for understanding the impact of the recent fall in oil prices on investor valuation of oil and gas reserves.

Key words: Oil and gas reserves, reserves replacement, stock returns

1. Introduction

Oil and gas reserves are clearly the most important assets that oil and gas companies have. The main objective of holding petroleum reserves is to generate future cash flows when they are extracted from oil and gas reservoirs and subsequently monetized. Replacing reserves as they are produced is crucial for the sustainability of their business model, and therefore an aspect of the industry that is followed closely by financial markets. Oil companies can pursue two main strategies for reserves replacement. They can either engage in risky exploration activities or purchase reserves from other agents. An interesting research question is how additions from organic growth through discoveries compare to reserve replacement through acquisition activities in terms of effects on security returns. On a risk adjusted basis, an investor should be indifferent between organic growth and acquisitions. In this study we address this issue and empirically examine if this is the case.

While the literature suggest that there is an empirical relationship between changes in petroleum reserves and security returns (see e.g. Clinch and Magliolo, 1992; Spear 1994; Berry et al., 1998; Boyer and Filion, 2007), few studies have addressed the relative importance of the different types of reserves additions and deductions (see e.g. Spear, 1994). Oil and gas companies can grow their

reserves in several ways. On the one hand they can engage in extremely risky exploration activities in order to grow their reserves base. In addition, they may focus on improving their technology to extract more of their resources. Or, they may purchase reserves from other companies. We aim to shed some light on the relative importance of the different components of reserves changes.

An interesting research topic is whether the stock markets put equal value on proved reserves from organic resource growth and from acquisitions. Are the markets indifferent to oil and gas companies' opposing strategies for reserves growth? Furthermore, we wish to examine if there are differences between returns and discoveries of oil or gas reserves, or between returns and acquisitions of oil or gas reserves.

To test this question we use the Ohlson (1995) framework combined with the insights from the multifactor framework of Sadorsky (2001) and Boyer and Filion (2007). This allows us to include both fundamental information such as profitability, common risk factors, and industry-specific information such as changes in oil and gas prices and changes in oil and gas reserves.

Changes in total reserves can attributed to revisions and improved recovery, extensions and discoveries, purchases of reserves-in-place, sales of reserves-in-place, and finally production. Increases in reserves can be attributed to upward revisions, improved recovery, extensions, discoveries and purchases, while decreases in reserves are due to downward revisions, sales of reserves and production. We estimate four empirical models, the differences related to how the oil and gas reserves are decomposed. In the first model we only examine the association between returns and the changes in total oil and gas reserves. Then, the next model decomposes total reserves into gas and oil reserves. The third model examines the seven subcomponents of changes in total oil and gas reserves, while the fourth model expands with a further decomposition into oil and gas reserves. The focus of our study is related to two of the seven subcomponents, namely discoveries and acquisitions. A priori, we expect that the coefficients on changes in reserves due to discoveries are similar to those of acquisitions since we control for systematic risk using several risk factors. We find a stepwise approach relevant for two reasons. Firstly, stability in the parameters offers insight into the robustness of the modeling procedure. Secondly, this approach also indicates if disaggregating total reserves into its subcomponents is meaningful.

We use a total of six common risk factors, including the Fama-French-Carhart (Fama and French, 1993; 1996; Carhart, 1997) risk factors and changes in oil and gas reserves. Our sample consists of 4218 firm-years for North American and international oil and gas companies.

The results show that stock returns are associated with changes in oil and gas reserves. In line with expectations, the results suggest that investors do not seem to differentiate between changes in total oil and gas reserves from acquisitions or from purchases. However, this is not that case when the changes in reserves are split into changes in oil reserves and changes in gas reserves. While the coefficients on oil reserve discoveries are higher than oil reserve purchases, the situation is opposite for changes in gas reserves. A possible explanation can be related to the increase in tight gas (shale gas) discovery and production since the late 2000s and the consequent fall in natural gas prices in the U.S. At the same time oil prices have diverged from natural gas prices. Hence, the difference between the relation between security returns and discoveries or acquisitions oil versus gas reserves can be linked to specific developments associated with the Shale gas revolution since 2009.

Furthermore, returns are positively associated with increased oil production, but are not significantly affected by increases in natural gas production.

Our contribution is twofold. First, Boyer and Filion (2007) find that the return of Canadian energy stocks is positively associated with changes in proved oil and gas reserves. We examine if and to what extent the subcomponents of changes in proved oil and gas explain the variation in oil company returns. This is important information for investors in the energy sector. Arguably, since the reserve additions and reductions are all measured as proved reserves, financial markets should not distinguish between the changes in reserves from acquisition or organic activities. Moreover, any differences in systematic risk should be captured by the four risk factors. If the markets price reserves growth from acquisitions differently from organic growth, this could potentially represent an arbitrage opportunity for investors, and the results from the empirical models can provide some insight into this topic. Second, we include several risk factors (e.g. Fama-French-Carhart four-factor model), and find that several common risk factors are important variables for explaining the variation in oil and gas shareholder returns. Prior studies (e.g. Sadorsky, 2001; Boyer and Filion, 2007) typically only include the market risk premium. We demonstrate that also other variables such as the small-minus-big, high book-equity ratio minus low book-equity ratio and momentum can help explain oil company stock returns.

The remainder of the paper is as follows. The next section presents the prior literature and provides a description of oil and gas reserves relevant for this study. Section 3 describes the Ohlson (1995) and develops the empirical models, incorporating also the findings from earlier empirical studies. Section 4 describes the data, followed by section 5 which presents and discusses the results. Section 6 concludes.

2. Background and literature
What explains oil and gas stock returns?
Empirical investigations into the returns of oil companies has been the topic of numerous academic studies (see e.g. Cunado and Gracia (2014), Chang and Yu (2014), and Mollick and Assefa (2014) for recent examples). One strand of the literature examines the relationship between oil prices and aggregate stock returns (Jones and Kaul, 1996; Huang et al., 1996; Sadorsky, 1999, Ciner 2001; Diesprong et al 2008; Apergis and Miller, 2009; Killian and Park, 2009; Elyasiani et al 2011; Narayan and Sharma, 2011, Lee at al 2012; Scholtens and Yurtsev, 2012; Park and Ratti, 2008; Güntner, 2013; Cunado and de Gracia, 2014; Nanda and Faff, 2008). Another strand examines the effect of oil prices on industry sectors including the oil and gas sector (Elyasiani et al 2011; Scholtens and Yurtsev, 2012; Lee et al., 2012; Gogieneni, 2010; Kilian and Park, 2009; McSweeney and Worthington, 2007; Hammoudeh, Dibooglu and Aleisa, 2004; Faff and Brailsford, 1999; Ramos and Veiga, 2011). And another focusses on the effect of oil prices on individual oil and gas stocks (see e.g. Hilliard and Danielsen, 1984; Al-Mudhaf and Goodwin, 1993; Aleisa et al., 2003; Sadorsky 2001; Sadorsky, 2008; Talbot et al., 2013; Scholtens and Wang, 2008; Hammoudeh and Li, 2005; Nanda and Hammoudeh, 2007; Lanza et al., 2003). The general impression from this strand of the literature is that commodity prices, such as oil and gas prices, influence the stock markets and in particular the returns on oil and gas companies.

Despite the substantial amount of research on the effect of commodity prices on aggregate, energy industry-specific and individual oil and gas stock returns, few studies assess the impact of

fundamental information such as the impact of changes in production and oil and gas reserves on stock returns.

Using quarterly returns for Canadian firms set in a multifactor framework, Boyer and Filion (2007) find that the return on oil and gas stocks is positively associated with the Canadian stock market return, with increases in oil and natural gas prices, growth in internal cash flows and proven reserves. Surprisingly, the authors find a negative relationship between oil stock returns and changes in production of oil and gas.

Scholtens and Wagenaar (2011) examine how revisions of petroleum reserves impact oil and gas company returns. Analyzing a total of 100 revisions in several countries between 2000 and 2010, the authors find that revisions significantly impact shareholder values. In fact, they uncover an asymmetric response whereby downward revisions had a much larger impact on returns than upward revisions did.

Kretzschmar and Kirchner (2009), examine the impact on oil stock returns of reserve location, addressing the concerns raised by Kretzschmar et al. (2007) and Osmundsen (2010) relating to the impact of contractual issues on the reserves ownership.[1] Data for 51 oil and gas companies 1998-2006.

Other studies find that exploration activities are related to returns. Misund, Mohn and Sikveland (2015), using an augmented Fama-French (Fama and French, 1996) four factor model, find a significant risk premium associated with exploration activity. Furthermore, Berry and Wright (2001) find that both exploration effort and success has an impact on oil company valuation.

Relevant research can also be found in the accounting literature (Magliolo, 1986; Harris and Ohlson, 1987; Clinch and Magliolo, 1992; Alciatore, 1993; Spear, 1994, 1996; Quirin et al 2000; Boone, 2002; Mohanty et al., 2013). Several of these studies address the association between the standardized measure and market valuation. The earliest studies found a weak relationship between net present values of reserves and company valuation (Magliolo, 1986; Harris and Ohlson, 1987). A later study by Alciatore (1993), using a sample for the period 1982 to 1984, found that disaggregation of the standardized measure into ten components provided additional information compared to changes in total reserves. This finding is corroborated by Spear (1994). In fact, Boone (2002) revisiting the Harris and Ohlson (1987) study came to a different conclusion. Hence, the literature suggests that reserve value estimates are value relevant. However, the results for reserves amounts are mixed. Clinch and Magliolo (1992) find an impact of reserve quantity on valuation for only a subset of firms. On the other hand, Spear (1994), using a sample of oil companies for 1984 to 1988, find that disaggregating reserve quantity changes into subcomponents conveys additional information compared to changes in total reserves. Spear's (1994) result for reserve quantities are consistent with the results for reserves values (e.g. Alciatore, 1993 and Spear, 1996). Moreover, both Spear (1994) and Alciatore (1993) find that discoveries are significantly associated with security returns, while the results on the impact of purchases are mixed. However, neither

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[1] Production Sharing Agreements (PSA) and concessionary ownership represent different ownership and entitlements of reserves. PSA agreements are usually found in non-OECD countries, while agreements in OECD countries are dominated by concessions (see Kretzschmar et al. (2007) for a discussion on the impact of contractual agreements on reserves entitlement).

study addresses the differential impact of oil and gas reserves on returns. Moreover, the reserves-returns relationship may vary over time, implying that it is important to also address this issue. In fact, studies suggest that in certain time periods exploration efforts may have adverse effects on market valuation (McConnell and Muscarella (1985), Picchi (1985) and Jensen (1986, 1988)). In recent years, an industry event that may have influenced the reserves-returns relationship, and particular for gas reserves, is the Shale gas revolution of the late 2000s. Improved technology led to several large discoveries, rapid development and production of natural gas from tight gas formations in the U.S. As a consequence, natural gas prices dropped, and are currently still at historical lows. This break in the oil-gas link may have had a substantial impact on the relative association between security returns and reserve amount changes for natural gas compared to oil since 2008.

In summary, different strands of the literature suggest that oil and gas prices, fundamental and operational information in addition to profitability can explain the variation in oil company returns. In particular, research shows that fundamental information such as reserves and production, reserves net present value, in addition to exploration activity and success impacts shareholder returns. Furthermore, studies using data samples for the 1980s indicate that reserves growth by discoveries has a significant impact on returns, but this is not the case for reserves appreciation through acquisitions. In contrast to the prior literature, we address all of these issues in a more formal theoretical framework. Ohlson (1995) develops a model that explains the value of equity (and also returns) as a function of current profitability, the cost of capital and 'other information'. The latter variable includes the information that explains future profitability. A relevant guide for future profitability and expected cash flow is the amount of oil and gas reserves.

Oil and gas reserves
One of the distinguishing factors for the oil and gas sector compared to other industries is the concept of reserves. Adelman and Watkins (2008) describe reserves as a "depletable" resource stock, limited by nature and doomed to decline. Oil and gas reserves are by far the most important assets that oil and gas companies own. Financial analysts and investors pay great attention to information related to reserve changes released from these companies. As a consequence, successful exploration will often result in substantial stock price appreciation. When the Swedish oil company Lundin on 30th September 2011 announced a significant discovery of oil and gas in Johan Sverdrup field on the Norwegian continental shelf, their share price appreciated more than 30% in one day. Conversely, decreases in reserves, due to downward revisions, can also have a huge impact on share prices. In January 2004, when Shell announced a 28% downward revision of their proved oil and gas reserves[2], their share price fell 12% over the 3-4 weeks following the announcement. Moreover, Scholtens and Wagenar (2011), analyzing 100 reserves revisions globally, found a significant impact on share prices.

Most academic studies have applied proved reserves when examining the relationship between reserves changes and returns. According to Osmundsen (2010), the information value of booked reserves (proved reserved) suffers from a number of weaknesses. First, reserves are recognized as profitable using average commodity prices over the previous fiscal year. Second, ownership and entitlement to the reserve and production are governed by contractual issues such as production sharing agreements versus concessions (see Bindemann (1999) and Kretzschmar et al (2007) for a

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[2] Royal Dutch Shell plc announced that they downgraded their reserves from proved to probable.

discussion on this topic). Finally, the estimation of reserves is not straightforward proved reserves is only one of several reserves classifications. The Society of Petroleum Engineers (SPE, 2011) characterizes petroleum reserves according to maturity and probability of recoverability (see Figure 1). Commercial reserves are classified as proved, probable or possible reserves.
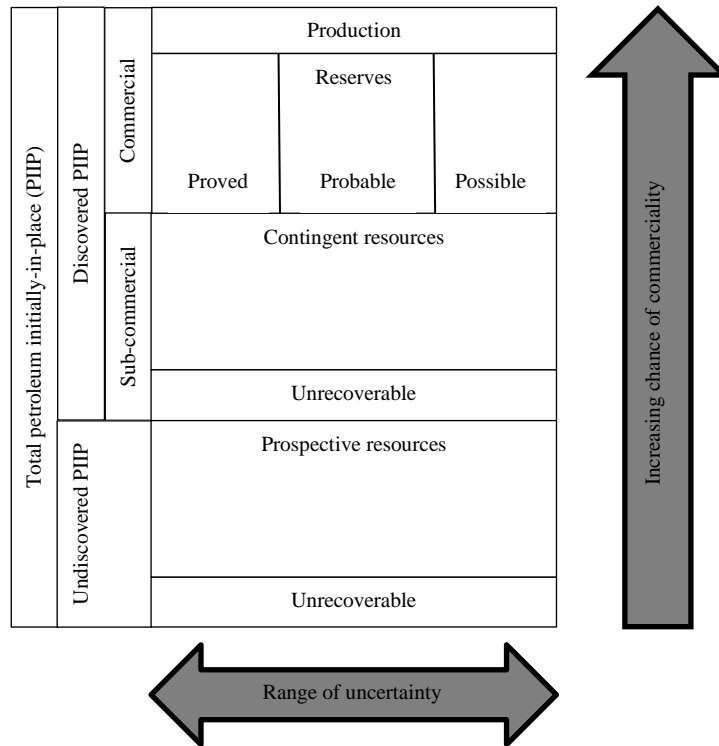

Figure 1: Society of Petroleum Engineers' oil and gas reserves classification framework. Source: Society of Petroleum Engineers (2011).

A recent study, however, finds that investors only to a limited degree rely upon less mature reserves (Misund and Osmundsen, 2015). We therefore find it appropriate to use proved reserves in our empirical study.

Since the early 1980s, both the U.S. Securities and Exchange Commission (SEC) regulation and Financial Accounting Standards Board (FASB) accounting standards require oil and gas companies to disclose a substantial amount of supplementary information in addition to the standard financial reporting requirements such as income statement, balance sheet, cash flows and notes (SEC, 2008; FASB 1977; 1982; 2009; 2010). The supplementary information relating to oil and gas exploration and production activities include a plethora of information. For instance, the oil major Exxon Mobil, in their 2013 10-K report, disclosed information on

- Results of operations related to oil and gas activities, according to geographical location.
- Oil and gas exploration and production costs (net capitalized costs, costs incurred in property acquisitions, exploration and development activities), according to geographical location.

- Proved reserves for crude oil, natural gas and unconventional petroleum, and across geographical location, both total and disaggregated.
- The standardized measure of discounted future cash flows, according to geographical location.
- Change in standardized measure of discounted future net cash flows relating to proved oil and gas reserves.

The changes in reserves amounts are split across geography, type of product (oil, gas or unconventional) and are also disaggregated into sources and uses. The latter is a decomposition of the year-to-year change in booked reserves into the following elements

1. Revisions and improved recovery
2. Extensions and discoveries
3. Purchases of reserves-in-place
4. Sales of reserves-in-place
5. Production

Positive reserves growth can thus be attributed to i) organic growth through exploration and development, ii) growth through technology improvements and upward revisions, and iii) reserves additions through acquisitions. Conversely, a negative reserves growth can be realized through iv) downward revisions, v) sales of reserves and vi) production.

In our study we will compare organic growth through extensions and discoveries with growth by way of acquisitions, by examining their association with returns. Moreover, we will examine if there are differences for oil versus gas, and if the reserves changes-returns relationship changes as an effect of an event such as the shale gas revolution.

3. Methodology
Following Jorion (1990) and Sadorsky (2001), Boyer and Filion (2007), we apply a multifactor framework, regressing excess return of oil and gas stocks on a set of common risk factors and fundamental variables. The common risk factors are the market risk premium, exchange rates, interest rates and oil and gas prices. The fundamental variables are changes in reserves, production as well as financial leverage and cash flows. We improve on the approach applied by Boyer and Filion (2007) in five ways. First, the inclusion of both changes in reserves and production as explanatory variables can potentially be problematic since changes in reserves also includes changes in production and can therefore be correlated. Furthermore, since changes in reserves can be decomposed to several components, leaving out several of these may lead to the omitted variables bias. Our approach is therefore to include all the subcomponents of reserves in the empirical model. Secondly, we incorporate the common risk factors and a measure for profitability, namely cash flow from operations, in the Ohlson (1995) model. Thirdly, we expand the set of common risk factors to include the Fama-French-Carhart risk factors. We have not found studies explicitly including the Fama-French-Carhart risk factors for explaining the variation in oil and gas company returns. Fourth, we explicitly examine the impact of oil versus gas reserves changes on oil firm returns. Lastly, we use panel date techniques to control for unobservable effects.

The Ohlson (1995) framework

Based on the hypothesis that asset prices represent the present value of all future dividends, Ohlson (1995) models the returns on stock prices to profitability and the discount rate

$$p_t = b_t + \alpha_1 x_t^a + \alpha_2 v_t, \text{ where } \alpha_1 = \omega/(k - \omega) \text{ and } \alpha_2 = k/(k - \omega)(k - \gamma), \tag{1}$$

where p_t is the stock price at time t, b_t is the book value of equity at time t, x_t^a is the profitability at time t measured as earnings less the expected return on equity, and v_t is value relevant information not yet captured by current measures of profitability ("other information"). The discount rate is denoted by k, and $0 \leq \omega$ and $\gamma < 1$ are constants. In addition to Eq. (1), Ohlson (1995) also develops a model for stock price returns as a function of shocks to earnings and other information

$$r_t = k + (1 + \alpha_1) \vartheta_t/p_{t-1} + \alpha_2 \eta_t/p_{t-1}, \tag{2}$$

where r_t is the total shareholder return, i.e. the sum of stock price return and dividend yield, and ϑ_t and η_t are mean zero disturbance terms (shocks) for earnings and other information, respectively. The theoretical model in Eq. (2) can be estimated using the following empirical model

$$r_{it} - RF_t = \theta_0 + \alpha_1 E_{it}/p_{it-1} + \alpha_2 \Delta E_{it}/p_{it-1} + \lambda R_t + \delta ogr_{it} + \varepsilon_{it}, \tag{3}$$

where r_{it} is the total shareholder return for company i at time t, E_{it} is the earnings for company i for the period from t-1 to t, and ΔE_{it} is the change in earnings from the previous time period. RF_t is the risk free rate at time t. The vector R_t in Eq. (2), denotes a set of common risk factors including the Fama-French-Carhart (MRP_t is the market risk premium, SMB_t and HML_t are the returns on the Fama-French (1993; 1996) Small-minus-big and high-minus-low factor, respectively. MOM_t is the Carhart (1997) momentum factor,[3]) and commodity price risk factors (ΔOP and ΔGP for the changes in oil and gas price, respectively). The last element in Eq. (3), ε_{it} is the error term. Earnings and changes in earnings are included to capture the shocks in earnings, while the Fama-French-Carhart factors are included as a proxy for the discount rate. In addition, we include changes in oil and gas prices since they are known to influence stock price returns (Sadorsky, 2001; Boyer and Filion, 2007). Moreover, oil and gas companies are allowed to choose between two competing methods for accounting for pre-discovery costs. Under the successful efforts method, only costs related to successful discoveries are allowed to be capitalized, and costs associated with dry holes are directly expensed. Whereas, under the competing method, the full cost method, all costs from exploration activities are booked on the balance sheets. The two methods can result in substantial differences in net income for the same firm if it was to change accounting method (Cortese et al., 2009). Consequently, the literature suggests that cash flow from operations can be more appropriate profitability measures in the oil and gas sector than earnings (see e.g. Dechow, 2004; Cormier and Magnan, 2002; deFond and Hung, 2003; Misund, 2015). We therefore use cash flow from operations and changes in cash flow from operations as proxies for earnings and changes in earnings, respectively, in Eq. (3).

The last variable, *ogr*, denotes a vector of oil and gas reserves variables (on changes form), and is decomposed in four ways in our study. In the first empirical model (Model 1), *ogr* represents the changes in total oil and gas reserves, while Model 2 uses both the changes in oil and gas reserves

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[3] The momentum effect was originally identified by Jegadeesh and Titman (1993).

as separate explanatory variables. The third model (Model 3) splits **ogr** into the following components.

$$ogr_t = \frac{(BOE_t - BOE_{t-1})}{BOE_{t-1}} = rev_t + ext_t + imp_t + pur_t + sal_t + oth_t + pro_t \qquad (4)$$

where the BOE_{t-1} and BOE_t are total reserves amounts (in barrels of oil equivalent) at the beginning and end of the fiscal year, respectively. The changes in total oil and gas reserves can further be attributed to revisions (rev_t), extensions and discoveries (ext_t), improved recovery (imp_t), purchases of reserves (pur_t), sales of reserves (sal_t), other reasons (oth_t) and production (pro_t). All amounts of reserves are denoted in barrels of oil equivalent. Natural gas reserves are normally measured in billions of cubic feet, which are converted to oil equivalents by dividing by dividing by a factor of six. All changes in reserves components use the beginning of year barrels of oil equivalents in the denominator. In the final model (Model 4), the subcomponents in Model 3 are split further by commodity type, oil or gas. The four empirical models are as follows:

Model 1
$$R_{it} = \alpha_0^1 + \alpha_1^1\, CF_{it}/p_{it-1} + \alpha_2^1\, \Delta CF_{it}/p_{it-1} + \sum_{j=1}^{6} \lambda_j^1\, R_t^j$$
$$+ \delta^{total} ogr_{it} + \varepsilon_{it}^1 \qquad (5)$$

Model 2
$$R_{it} = \alpha_0^2 + \alpha_1^2\, CF_{it}/p_{it-1} + \alpha_2^2\, \Delta CF_{it}/p_{it-1} + \sum_{j=1}^{6} \lambda_j^2\, R_t^j$$
$$+ \delta^{gas} ogr_{it} + \delta^{oil} ogr_{it} + \varepsilon_{it}^2 \qquad (6)$$

Model 3
$$R_{it} = \alpha_0^3 + \alpha_1^3\, CF_{it}/p_{it-1} + \alpha_2^3\, \Delta CF_{it}/p_{it-1} + \sum_{j=1}^{6} \lambda_j^3\, R_t^j$$
$$+ \sum_{l=1}^{7} \delta_l^{total} ogr_{it}^{l,total} + \varepsilon_{it}^3 \qquad (7)$$

Model 4
$$R_{it} = \alpha_0^4 + \alpha_1^4\, CF_{it}/p_{it-1} + \alpha_2^4\, \Delta CF_{it}/p_{it-1} + \sum_{j=1}^{6} \lambda_j^4\, R_t^j$$
$$+ \sum_{l=1}^{7} \delta_l^{oil} ogr_{it}^{l,oil} + \sum_{l=1}^{7} \delta_l^{gas} ogr_{it}^{l,gas} + \varepsilon_{it}^4 \qquad (8)$$

where the dependent variable R_{it}, are total shareholder returns for oil and gas companies in excess of the the 1-month T-Bill rate, R_t^j are the Fama-French-Carhart factors, where j represents the four factors (j=1: Market risk premium, *MRP*; j=2: Small-minus-big, *SMB*; j=3: High minus low book-to-market, *HML*; j=4: is momentum factor, *MOM*; j=5: is the change in oil price, ΔOP and ; j=6: is the change in gas price, ΔGP). α_0 and ε_{it} are the intercept and residuals, respectively. Moreover, $ogr_{it}^{l,total}$ represents the changes in total oil and gas reserves, decomposed in seven sub-components, and where l represents the different sub-components (l=1: rev; l=2: ext; l=3: imp; l=4:

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pur; l=5: sal; l=6: oth; l=7: pro). Finally, The vectors $ogr_{it}^{l,oil}$ and $ogr_{it}^{l,gas}$ denote each of the seven l subcomponents for both oil and gas reserves changes.

In a similar study, Boyer and Filion (2007) include several variables such cash flow, reserves changes and production. We improve on Boyer and Filion in two ways. First, we apply an empirical specification that is based on a theoretical model which includes profitability, cost of capital and variables that capture future profitability, proxied by oil and gas reserves. Furthermore, we avoid using overlapping variables, since changes in reserves include changes in production and changes in the other reserves components. Our approach is decompose changes in total reserves into all the subcomponents as reported in the companies' supplements to their annual financial statements.

Panel data models
As Fields et al. (2001, p. 300) points out, accounting information, such as profitability, can often only explain a minor part of the variability share price returns. Therefore, if only accounting information, such as earnings and proved reserves, is included in the empirical model we run the risk of running into econometric issues such as the omitted variables bias. The problem with the omitted variables bias is that it can lead to biased estimators. Consequently, it is crucial to try to mitigate the omitted variables bias. One approach is to include control variables. However, it can be difficult to identify relevant control variables. Moreover, the significance and relevance of the control variables can vary over time, and from study to study, possibly because they proxy for some unidentified variable. Another approach is to apply panel data techniques such as fixed effects or random effects models. The benefit of a fixed effects model is that it can capture the effects of unobservable factors which are constant across time or constant across the firms in the sample. For instance, Boone (2002) finds an opposite result regarding the value relevance of the standardized measure compared to an earlier study by Harris and Ohlson (1987) by applying a fixed effects model. In order to mitigate the possible negative effects of omitted variables we apply panel data techniques. To find the appropriate panel model we carry out three diagnostics tests. First, we test if we should use a panel model (fixed effects or random effects) instead of pooled OLS. Next, we test between random effects and fixed effects using the Hausman test.

To mitigate the negative impact of heteroscedasticity, robust standard errors are calculated to correct for heteroscedasticity and serial correlation in the error terms (Arellano, 1987).

Hypotheses
We test three hypotheses relating to the association between reserves quantities and oil and gas company shareholder returns.

Hypothesis 1: Organic growth versus Acquisition
H0: (total reserves): coefficients on changes in reserves extensions and discoveries (organic growth) are the same as coefficients on changes in purchased reserves (acquisitions). Formally, this is a F-test of coefficient equality, $\delta_{ext} - \delta_{pur} = 0$. If the null hypothesis is rejected then the results provide evidence that investors value changes in reserves due to discoveries differently than changes in reserves due to acquisitions.

Hypothesis 2: Gas versus oil

H_0: (oil and gas reserves): coefficients on changes in oil or gas reserves extensions and discoveries (organic growth) are the same as coefficients on changes in purchased oil or gas reserves (acquisitions)

Hypothesis 3: Structural shift: Impact of Shale gas revolution

H_0: There has been a structural shift in the coefficients on the interaction variables between gas reserves changes and a dummy variable for onset of the Shale gas revolution (the dummy variable equals one for years after 2008, and zero before or in 2008).

4. Dataset and variables

Our sample consists of accounting data and returns for a selection of oil and gas companies for the time period 1992 to 2013, comprising more than 20 years of data. The accounting data, both cash flow from operations and supplementary data on reserves, are collected from the IHS Herold database (www.ihs.com/herold). This database contains data on both North American and International companies. We use contemporaneous returns in our analysis. However, studies vary with respect to the use of contemporaneous (end of year minus end of year previous year) versus lagged returns (returns as of end of March versus end of March previous year). The arguments for the latter approach is that the accounting information is released after the end of the year, typically within the first 2 months following the year-end. Hence, the returns calculations should reflect this time discrepancy between year-end and disclosure of accounting information. However, this view does not take into account that some of the information is publically available before year-end and will be reflected in the share prices at year-end. For instance, an oil and gas company will typically inform the market of any major oil and gas discoveries. Likewise, oil and gas companies will also inform the market of purchases or sales of assets. Finally, production amounts are released on a quarterly basis, meaning that the market has received information on production changes for the first three quarters of the year. For these reasons, we use contemporenous returns in this study. This approach differs from event studies such as applied by Spear (1994).

The changes in oil and natural gas prices are calculated as the annual return on the front month futures contracts, and are collected from the U.S. Department of Energy (www.doe.gov/eia). Finally, the Fama-French-Carhart risk factors are extracted from Ken French' site. The descriptive statistics are presented in Table 1. The mean change in reserves was 14.7 percent from 1992 to 2003. This indicates that the companies in the sample experienced a substantial growth in reserves. Most of the growth came from extensions and discoveries at 15.3 percent, followed by purchases at 11.3 percent average change. Production of reserves dominated the downward change in reserves at 11.1 percent per annum. The 14.7 percent increase in total reserves can be attributed to changes in oil and gas reserves of 8.2 and 6.5 percent, respectively.

Table 1. Descriptive statistics

Variable	Mean	St.dev.	25%	Median	75%	N
R	0.1648	0.5372	-0.1849	0.0942	0.4295	4218
CF	0.2103	0.2849	0.1087	0.1761	0.2617	4218
ΔCF	0.0268	0.2374	-0.0144	0.0215	0.0675	4218
MRP	0.0821	0.1945	0.0083	0.1069	0.2021	23
SMB	0.0323	0.1192	-0.0373	0.0039	0.0747	23
HML	0.0232	0.1588	-0.0795	0.0371	0.1321	23
MOM	0.0587	0.2343	0.0324	0.0863	0.1775	23
ΔOP	0.1458	0.4018	-0.0709	0.0815	0.3361	23
ΔGP	0.1753	0.7483	-0.2094	0.0527	0.2623	23
ΔBOE	0.1472	0.5404	-0.0485	0.0424	0.1951	4218
ΔBOE^{REV}	0.0108	0.2315	-0.0446	0.0045	0.0504	4218
ΔBOE^{EXT}	0.1532	0.3013	0.0159	0.0765	0.183	4218
ΔBOE^{IMP}	0.0069	0.0598	<0.0001	<0.0001	<0.0001	4218
ΔBOE^{PUR}	0.1133	0.3830	<0.0001	0.0042	0.0787	4218
ΔBOE^{SAL}	-0.0302	0.0937	-0.0168	-0.0004	<0.0001	4218
ΔBOE^{OTH}	0.0039	0.1067	<0.0001	<0.0001	<0.0001	4218
ΔBOE^{PRO}	-0.1111	0.0701	-0.1348	-0.0979	-0.0706	4218
ΔOIL	0.0820	0.4140	-0.0187	0.0099	0.0782	4218
ΔOIL^{REV}	0.0182	0.1724	-0.0100	0.0034	0.0283	4218
ΔOIL^{EXT}	0.0618	0.2287	0.0008	0.0193	0.0534	4218
ΔOIL^{IMP}	0.0051	0.0546	<0.0001	<0.0001	<0.0001	4218
ΔOIL^{PUR}	0.0559	0.2831	<0.0001	0.0004	0.0214	4218
ΔOIL^{SAL}	-0.0129	0.0521	-0.0048	<0.0001	<0.0001	4218
ΔOIL^{OTH}	0.0027	0.0780	<0.0001	<0.0001	<0.0001	4218
ΔOIL^{PRO}	-0.0489	0.0493	-0.0624	-0.0418	-0.0195	4218
ΔGAS	0.0650	0.2597	-0.0257	0.0064	0.0984	4218
ΔGAS^{REV}	-0.0072	0.1187	-0.0295	0.0000	0.0157	4218
ΔGAS^{EXT}	0.0916	0.1673	0.0021	0.0327	0.1141	4218
ΔGAS^{IMP}	0.0018	0.0203	0.0000	0.0000	0.0000	4218
ΔGAS^{PUR}	0.0574	0.1794	0.0000	0.0008	0.0307	4218
ΔGAS^{SAL}	-0.0173	0.0651	-0.0071	0.0000	0.0000	4218
ΔGAS^{OTH}	0.0012	0.0525	0.0000	0.0000	0.0000	4218
ΔGAS^{PRO}	-0.0624	0.0578	-0.0859	-0.0503	-0.0251	4218

Note: ΔBOE, ΔOIL, ΔGAS are changes in total oil&gas reserves, oil reserves and gas reserves, respectively. The superscript describes the type of disaggregated reserves; REV = revisions, EXT = extensions, IMP = improvements, PUR = purchases, SAL = sales, OTH = other, and PRO = production.

All variables we use in the empirical analysis are stationary (Table 2) and no first differencing is needed.

Table 2. Test for unit root using the Augmented Dickey-Fuller test (ADF)

Variable	BOE		OIL		GAS	
	ADF-value	p-value	ADF-value	p-value	ADF-value	p-value
R	-37.483	<0.001				
CF	-37.483	<0.001				
ΔCF	-31.190	<0.001				
MRP	-39.818	<0.001				
SMB	-40.948	<0.001				
HML	-42.172	<0.001				
MOM	-34.591	<0.001				
ΔOP	-51.559	<0.001				
ΔGP	-37.820	<0.001				
TOT	-34.130	<0.001	-35.541	<0.001	-31.424	<0.001
REV	-33.704	<0.001	-36.612	<0.001	-31.006	<0.001
EXT	-31.070	<0.001	-32.707	<0.001	-26.360	<0.001
IMP	-31.749	<0.001	-33.583	<0.001	-29.035	<0.001
PUR	-33.052	<0.001	-35.160	<0.001	-30.901	<0.001
SAL	-35.786	<0.001	-35.674	<0.001	-36.129	<0.001
OTH	-38.005	<0.001	-37.151	<0.001	-38.730	<0.001
PRO	-22.144	<0.001	-21.238	<0.001	-20.668	<0.001

Note. For simplicity the ADF results are split into three, for changes in total reserves (columns 2 and 3), changes in oil reserves (columns 4 and 5), and changes in gas reserves (columns 6 and 7). The variable for changes in total, oil and gas reserves attributed to purchases is denoted by *PUR* in this table (across three columns), but ΔBOE^{PUR}, ΔOIL^{PUR}, and ΔGAS^{PUR}, respectively in Table 1. *TOT* = total reserves, *REV* = revisions, *EXT* = extensions, *IMP* = improvements, *PUR* = purchases, *SAL* = sales, *OTH* = other, and *PRO* = production.

5. Results and discussion

In this section we present the results from the empirical analysis. We do this in several steps. First, we examine which type of panel models are appropriate using three tests. Two pooling test will indicate if we should use pooled OLS or fixed or random effects. Then, we apply a Hausman test to see if random effects is better than fixed effects. Secondly, we test the null hypotheses of no heteroskedasticity or serial correlation in the residuals. If we fail to reject the hypotheses, we need to correct the standard errors in the coefficients of the regressions before making inferences. Finally, we estimate four different empirical models.

The diagnostics tests indicate that we should use random effects for Model 1 and fixed effects for Models 2 to 4 (Table 3). Furthermore, the data shows the presence of both heteroskedasticity and serial correlation and we therefore apply the Arrelano (1987) approach for correcting the standard errors of the four empirical models.

Table 3. Panel data tests and tests for heteroskedasticity and serial correlation

	Model 1	Model 2	Model 3	Model 4
Pooled vs fixed	1.370 (<0.001)	1.357 (<0.001)	1.370 (<0.001)	1.364 (<0.001)
Pooled vs random	82175.8 (<0.001)	81491.9 (<0.001)	81503.4 (<0.001)	80123.9 (<0.001)
Random vs Fixed	6.900 (0.648)	18.879 (0.042)	96.521 (<0.001)	94.434 (<0.001)
Heteroskedasticity	999.646 (<0.001)	909.629 (<0.001)	1103.993 (<0.001)	973.135 (<0.001)
Serial correlation	<0.001 (0.982)	50.538 (<0.001)	47.283 (<0.001)	51.357 (<0.001)

Note. *Pooled vs fixed* has H_0: Pooled model is a better fit than a fixed effects model (F-test). *Pooled vs random* has H_0: Pooled model is a better fit than a random effects model (Breusch-Pagan test: Breusch and Pagan (1979)). *Random vs fixed* has H_0: Random effects model is a better fit than a fixed effects model (Hausman test: Hausman, 1978). Presence of heteroskedasticity is tested using a Breusch-Pagan test (Breusch and Pagan, 1979) with H_0: no heteroskedasticity present in the data, and presence of serial correlation is tested using a Breusch-Godfrey/Wooldridge test (Breusch, 1978; Godfrey, 1978; and Wooldridge, 2002) with H_0: no serial correlation present in the data.

Table 4 presents the results for the empirical estimation of the four models. In Model 1, both cash flow from operations and changes in cash flow are statistically significant. Moreover, three of the common risk factors, market risk premium, small-minus-big and high-minus-low, contribute to

explaining the variation in oil and gas company returns. Furthermore, both oil and gas prices are positively associated with market valuations. In line with previous studies such as Boyer and Filion (2007), we find that changes in total oil and gas reserves impact security returns. However, our results contradict Osmundsen et al. (2006) who did not find a significant relationship between the reserves replacement ratio (RRR) and valuation of large international oil and gas companies. However, the latter study used valuation multiples instead of returns, which could explain the differences in results. The methodology in our study is more comparable to Boyer and Filion (2007).

In Model 2 we expand Model 1 by examining the differential effect of changes in oil versus gas reserves. The results show that both oil and gas reserves impact returns, but the coefficient on gas is more than three times higher for the latter variable (gas: 0.274 and oil: 0.083). The *F*-test confirm that they are also statistically different from each other. This result suggests that changes in gas reserves has had a bigger impact on returns than oil reserves have.

Table 4. Regression results

Variable	Model 1	Model 2	Model 3	Model 4
Intercept	**-0.057 (-2.961)**			
CF	**0.178 (1.898)**	**0.277 (2.424)**	**0.271 (2.400)**	**0.285 (2.452)**
ΔCF	**0.171 (2.373)**	0.081 (1.391)	**0.102 (1.733)**	0.085 (1.454)
MRP	**0.524 (14.872)**	**0.587 (16.176)**	**0.588 (16.462)**	**0.584 (16.146)**
SMB	**0.321 (3.619)**	**0.289 (3.224)**	**0.273 (3.034)**	**0.292 (3.231)**
HML	**0.890 (11.781)**	**0.886 (11.321)**	**0.890 (11.478)**	**0.889 (11.429)**
MOM	0.073 (1.614)	**0.133 (2.934)**	**0.133 (2.917)**	**0.129 (2.834)**
ΔOP	**0.394 (13.835)**	**0.381 (13.290)**	**0.383 (13.394)**	**0.383 (13.455)**
ΔGP	**0.105 (6.859)**	**0.106 (6.849)**	**0.105 (6.803)**	**0.105 (6.774)**
ΔBOE	**0.161 (6.743)**			
ΔBOE^{REV}			**0.114 (2.092)**	
ΔBOE^{EXT}			**0.165 (2.955)**	
ΔBOE^{IMP}			-0.113 (-1.368)	
ΔBOE^{PUR}			**0.167 (5.749)**	
ΔBOE^{SAL}			0.041 (0.402)	
ΔBOE^{OTH}			-0.012 (-0.159)	
ΔBOE^{PRO}			0.217 (1.216)	
ΔOIL		**0.083 (3.135)**		
ΔOIL^{REV}				0.061 (0.990)
ΔOIL^{EXT}				**0.127 (1.731)**
ΔOIL^{IMP}				-0.107 (-1.343)
ΔOIL^{PUR}				**0.065 (2.978)**
ΔOIL^{SAL}				0.144 (0.968)
ΔOIL^{OTH}				0.103 (0.892)
ΔOIL^{PRO}				**0.691 (1.897)**
ΔGAS		**0.274 (5.829)**		
ΔGAS^{REV}				**0.244 (2.235)**
ΔGAS^{EXT}				**0.252 (3.240)**
ΔGAS^{IMP}				-0.205 (-0.711)
ΔGAS^{PUR}				**0.381 (6.201)**
ΔGAS^{SAL}				-0.001 (-0.003)
ΔGAS^{OTH}				-0.150 (-1.006)
ΔGAS^{PRO}				0.197 (1.055)
Adjusted R^2	0.272	0.252	0.250	0.256
F-statistic	175.160 (<0.001)	149.223 (<0.001)	98.354 (<0.001)	69.206 (<0.001)
RE/FE/pooled	RE	FE	FE	FE

Note: RE is random effects and FE is fixed effects. Δ*BOE*, Δ*OIL*, Δ*GAS* are changes in total oil&gas reserves, oil reserves and gas reserves, respectively. The superscript describes the type of disaggregated reserves; *REV* = revisions, *EXT* = extensions, *IMP* = improvements, *PUR* = purchases, *SAL* = sales, *OTH* = other, and *PRO* = production.

In Model 3 we extend Model 1 by examining the impact of the subcomponents of the change in total oil and gas reserves on returns. As the results in Table 4 suggest, the investors are indifferent

between changes in total reserves due to organic growth through extensions and discoveries and acquisition of reserves. The results of the F-test also confirms this (Table 5).

Table 5. F-tests and Chow-test

Hypotheses	F-statistic (p-value)	χ^2-statistic (p-value)
Hypothesis 1		
Model 2: H$_0$: $\delta_{tot}^{oil} - \delta_{tot}^{gas} = 0$	10.804 (0.001)	
Model 4: H$_0$: $\delta_{ext}^{oil} - \delta_{ext}^{gas} = 0$	1.250 (0.264)	
Model 4: H$_0$: $\delta_{pur}^{oil} - \delta_{pur}^{gas} = 0$	16.097 (<0.001)	
Hypothesis 2		
Model 3: H$_0$: $\delta_{ext}^{boe} - \delta_{pur}^{boe} = 0$	<0.001 (0.976)	
Model 4: H$_0$: $\delta_{ext}^{oil} - \delta_{pur}^{oil} = 0$	0.299 (0.587)	
Model 4: H$_0$: $\delta_{ext}^{gas} - \delta_{pur}^{gas} = 0$	1.774 (0.183)	
Hypothesis 3		
H$_0$: no structural shift on interaction terms on oil reserves changes		9.720 (0.205)
H$_0$: no structural shift on interaction terms on gas reserves changes		22.812 (0.002)

Model four examines the impact of disaggregate oil versus gas reserves. Although the coefficients vary between 0.065 and 0.381 for changes in oil and gas reserves attributed to purchases and acquisitions, they are in general not statistically significant from each other. As indicated in Table 5, only the coefficients on gas purchases and oil purchases are statistically significantly different. This result suggests that investors are indifferent between increases in oil and gas reserves due to discoveries. However, they do separate between oil and gas reserve changes from acquisitions, placing a higher loading on acquisition of gas reserves.

Contrary to Boyer and Filion (2007), we do find that oil and gas company returns are positively associated with production. However, we only find evidence that this is valid for oil reserves, not gas reserves. Hence, it seems that oil production is the primary production measure that investors use in the oil and gas sector.

In the last part of the analysis we examine if there has been a structural shift in the reserves-returns relationship before and after 2008/2009. We hypothesis that only the coefficients on gas reserves have been affected, and expect the coefficients on oil reserve changes remain unchanged. This hypothesis is tested using the Chow test. The results confirm our expectations (Table 6). Moreover, the Chow test for gas reserve interactions formally confirms this (Chi-sq. = 22.812, p-value = 0.002). The Chow test for the interaction coefficients on the oil reserves is not significant. Hence, the results provide evidence that there has been a structural shift in the gas reserves-return relationship that coincides in time with the Shale gas revolution and the break in the gas-oil link.

Table 6: Shale gas

Variable	Pre-2008	Post-2008
Intercept		**-0.174 (-3.911)**
ΔOIL^{REV}	0.044 (0.805)	0.151 (1.310)
ΔOIL^{EXT}	0.101 (1.162)	0.104 (0.720)
ΔOIL^{IMP}	-0.502 (-0.816)	0.445 (0.725)
ΔOIL^{PUR}	**0.081 (2.327)**	-0.044 (-0.725)
ΔOIL^{SAL}	0.155 (0.800)	-0.022 (-0.064)
ΔOIL^{OTH}	**0.200 (1.646)**	-0.621 (-1.543)
ΔOIL^{PRO}	**0.849 (2.102)**	-0.566 (-1.120)
ΔGAS^{REV}	0.065 (0.576)	**0.566 (3.073)**
ΔGAS^{EXT}	**0.268 (3.069)**	-0.167 (-1.213)
ΔGAS^{IMP}	-0.289 (-0.878)	**0.829 (2.021)**
ΔGAS^{PUR}	**0.336 (5.087)**	**0.412 (1.707)**
ΔGAS^{SAL}	0.100 (0.517)	-0.542 (-1.378)
ΔGAS^{OTH}	-0.110 (-0.419)	0.131 (0.351)
ΔGAS^{PRO}	0.187 (0.939)	-0.024 (-0.050)
Adjusted R^2	0.256	0.268
F-statistic	69.206 (<0.001)	44.047 (<0.001)

Note: For simplicity, only the coefficients on the reserves variables are presented. ΔBOE, ΔOIL, ΔGAS are changes in total oil&gas reserves, oil reserves and gas reserves, respectively. The superscript describes the type of disaggregated reserves; *REV* = revisions, *EXT* = extensions, *IMP* = improvements, *PUR* = purchases, *SAL* = sales, *OTH* = other, and *PRO* = production.

6. Conclusion

In this paper, we have examined the relation between changes in reserves and oil company stock returns, and specifically examined whether reserves changes attributed to exploration activities versus acquisitions of reserves are priced differently by investors. The empirical methodology is based on the Ohlson (1995) framework which explains stock returns in terms of current and future profitability (earnings) and the discount rate. As a proxy for the discount rate we incorporate the multifactor model approach adopted by Sadorsky et al. (2001) and Boyer and Filion (2007). We augment the latter studies by also including the Fama-French-Carhart risk factors in addition to the market risk premium.

The results show that stock returns are associated with changes in oil and gas reserves. In line with expectations, the results suggest that investors do not seem to differentiate between changes in total oil and gas reserves from acquisitions or from purchases. However, this is not that case when the changes in reserves are split into changes in oil reserves and changes in gas reserves. While the coefficients on oil reserve discoveries are higher than oil reserve purchases, the situation is opposite for changes in gas reserves. A possible explanation can be related to the increase in tight gas (shale gas) discovery and production since the late 2000s and the consequent fall in natural gas prices in the U.S. At the same time oil prices have diverged from natural gas prices. Hence, the difference between the relation between security returns and discoveries or acquisitions oil versus gas reserves can be linked to specific developments associated with the Shale gas revolution since 2009. This latter result is of relevance for understanding the impact of the recent fall in oil prices. During late 2014 to early 2015, crude oil prices fell from above 100 USD/barrel to below 50 USD/barrel. Many commentators attributed the substantial fall in oil prices to increased U.S. onshore shale oil production. Consequently, our results suggest that a similar structural break in the return-oil reserves might occur following the recent shale oil revolution.

Finally, we find that several common risk factors are important variables for explaining the variation in oil and gas shareholder returns. Prior studies typically only include the market risk

premium. We demonstrate that also other variables such as the small-minus-big, high book-equity ratio minus low book-equity ratio and momentum can help explain oil company stock returns. In this study we have applied the risk factors as common factors but it is also possible to include them as individual factors, e.g. a Fama-MacBeth approach.

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