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Abstract

This study examines whether mandated disclosure about the dispersion of the value of oil and gas (O&G) reserves provides information about firm risk. Based on a sample of Canadian O&G firms between 2004 and 2011, we find that the difference between the 10th and 50th percentiles of O&G reserves, which is a measure of dispersion of the reserves distribution, is positively associated with future total and idiosyncratic equity return volatility, systematic risk, and credit risk. We also find that disclosure of increases in reserves dispersion is associated with weaker stock price reactions to increases in reserve levels and with increases in bid-ask spreads, both of which indicate the disclosures convey information about risk associated with the reserves. Additional tests reveal it is unlikely that our findings are attributable to managerial opportunism in estimating reserves. Taken together, our study provides evidence that disclosures relating to the dispersion of non-financial asset values can provide information relevant to assessing firm risk.

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Firm Risk and Disclosures about Dispersion in Asset Values: Evidence from Oil and Gas Reserves

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Firm Risk and Disclosures about Dispersion in Asset Values: Evidence from Oil and Gas Reserves

Abstract:

This study examines whether mandated disclosure about the dispersion of the value of oil and gas (O&G) reserves provides information about firm risk. Based on a sample of Canadian O&G firms between 2004 and 2011, we find that the difference between the 10th and 50th percentiles of O&G reserves, which is a measure of dispersion of the reserves distribution, is positively associated with future total and idiosyncratic equity return volatility, systematic risk, and credit risk. We also find that disclosure of increases in reserves dispersion is associated with weaker stock price reactions to increases in reserve levels and with increases in bid-ask spreads, both of which indicate the disclosures convey information about risk associated with the reserves. Additional tests reveal it is unlikely that our findings are attributable to managerial opportunism in estimating reserves. Taken together, our study provides evidence that disclosures relating to the dispersion of non-financial asset values can provide information relevant to assessing firm risk.

Firm Risk and Disclosures about Dispersion in Asset Values: Evidence from Oil and Gas Reserves

I. INTRODUCTION

The question we address is whether mandated disclosure about the dispersion of the value of oil and gas (O&G) reserves provides information about firm risk.[1] Disclosures by Canadian O&G firms enable us to address this question empirically because Canada is unique in mandating disclosure of two points of the estimated probability distribution of the value of the largest asset of these firms, namely O&G reserves. These two points are the 10th and 50th percentiles of the distribution, which are referred to as "proved reserves" and "proved plus probable reserves" (henceforth P10 and P50). Because O&G reserves generally exhibit a lognormal distribution, the difference between P50 and P10 is a measure of the dispersion of the reserves distribution and, thus, risk associated with the reserves. Although O&G reserves are peculiar to the O&G industry and could be easier to value than non-financial assets in other industries, we study these reserves disclosures for two reasons. First, the O&G industry is economically important in its own right. Second, the disclosures enable us to provide evidence on whether the disclosure of the dispersion of the probability distribution of non-financial assets can be informative about firm risk.

The recent financial crisis revealed that financial statements or other mandatorily provided public disclosures do not portray transparently firm risk. The crisis focused attention primarily on the inadequacies of available information relating to financial firms about financial risk. However, non-financial firms can face substantial risk about non-financial risk that

[1] Firm risk is random variation, upside and downside, in the firm's future economic performance (e.g., Ryan 2012). Our study focuses on firm risk as reflected in total, systematic, and idiosyncratic equity risk as well as credit risk.

mandatory public disclosures also do not portray transparently. In addition, the increasing use of fair value accounting highlights the fact that fair values provide estimates of the mean of the present value of risky future cash flows associated with the asset or liability measured at fair value, but do not provide information about the risk associated with that value. Although disclosures relating to market and credit risks are mandatory, these disclosures generally are not quantitative and do not pertain to non-financial firms' primary operating assets. This raises the question of whether investors in non-financial firms might benefit from disclosure of information relating to the probability distribution of the value of such assets.

Disclosures of accurate estimates of the dispersion of O&G reserves likely are informative about variability in O&G firms' future performance. Because an O&G firm's ability to generate future revenues crucially depends on its reserves, the value of the firm depends on reserves value and risk. However, disclosures about reserves dispersion might not be informative about firm risk. First, if estimating reserves, e.g., P50, is too difficult, the disclosed amount could be noisy and, thus, uninformative. Second, firms could opportunistically manage disclosed reserve amounts, e.g., to manage investors' expectations or to circumvent contractual constraints, which could result in unreliable estimates. These concerns underlie the US Securities and Exchange Commission (SEC) prohibiting, until recently, disclosure of P50.

Cognizant of concerns regarding estimation difficulties and the potential for managerial opportunism, Canadian regulation includes requirements and monitoring mechanisms aimed at enhancing the faithful representation of the reserves. For example, the Alberta Securities Commission (ASC) annually monitors reported reserves, encourages establishment of a reserves committee comprising independent members of the firm's board of directors, and requires the appointment of an external evaluator to estimate or audit the reserves. In addition, firms engage

engineering consultants to provide assurance regarding the reserve amounts. The extent to which these factors, taken together, result in disclosures that reflect information about firm risk is an empirical question.

We base our analyses on a sample of 1,156 firm-year observations from 258 O&G firms listed on Canadian stock exchanges between 2004 and 2011, and proceed in three steps. In the first step, we test whether disclosed reserves dispersion is positively associated with firm risk. Because firm risk is not observable we use ex post measures of the risk borne by firms' equity and debt holders. In particular, we estimate the relations between the disclosed dispersion and total equity risk, i.e., the standard deviation of one-year-ahead daily returns; systematic risk, i.e., beta from the market model based on the one-year-ahead daily returns; and idiosyncratic risk, i.e., the standard deviation of the residuals from the market model. We also estimate the relation between the disclosed dispersion and credit risk, i.e., one-year-ahead net interest expense scaled by net debt. We find significant positive relations between disclosed dispersion and all four measures of firm risk. Our inferences apply to reserves measured in dollars and in barrels of oil equivalents (BOE), and are insensitive to inclusion of a variety of controls in our tests.[2]

In the second step, we focus on the stock market reaction—stock price change and change in bid-ask spread—to the disclosure of the dispersion information. Even if disclosed dispersion is informative about firm risk, the disclosure might not be the source of information if investors have private information about the reserves or assess firm risk without relying on the disclosed dispersion information. Thus, the market reaction tests complement those in the first step by linking the disclosed information to changes in investors' assessment of firm risk, thereby providing evidence that the reserves disclosure is informative about firm risk and is the

[2] One BOE is equivalent to 6,000 $ft.^3$ of natural gas.

source of investors' information. The tests also mitigate the concern that changes during the year in firm risk or market conditions affect the inferences we draw from the first-step analyses.

Regarding the stock price reaction, we test whether the stock price reaction to the reserves disclosure is weaker when the change in the disclosed reserves dispersion is larger. In particular, we estimate the relation between abnormal stock returns in a short window around the reserves disclosure and the change in the median reserves, separately for firms with high and low change in reserves dispersion. We find a significantly positive (insignificant) price reaction to change in median reserves when the change in reserves dispersion is low (high), which is consistent with our expectations. Regarding change in bid-ask spread, we estimate the relation between change in bid-ask spread in the short window around the reserves disclosure and the change in disclosed reserves dispersion. We find that the change in the disclosed dispersion is significantly positively associated with change in bid-ask spread.

In the third step, we provide evidence on the extent to which the disclosed reserves dispersion is associated with opportunistic management of the disclosed reserves amounts. In particular, we estimate the relation between the disclosed reserves dispersion and disclosure incentives and governance characteristics, incremental to controls for general firm characteristics and oil and gas-specific fundamentals. We find that disclosure incentives and governance characteristics have limited ability to explain the disclosed dispersion of reserves; oil and gas-specific fundamentals have a greater ability to explain it. We next test whether the disclosed reserves dispersion is associated with revisions of reserves estimates over the subsequent one to three years. If firms opportunistically inflate reserves in the current year, we expect the reserves to be revised downward in the future. We find no evidence of such an association. Finally, we test whether the disclosed reserves dispersion is associated with lower levels of reserves in the

subsequent year. Again, we find no evidence of such an association. Taken together, the findings are inconsistent with opportunistic management of the reserves amounts being a major factor in their estimation.

The study proceeds as follows. Section 2 describes the institutional background and related research. Section 3 describes the sample and data. Sections 4, 5, and 6 present the research design and findings relating to the association between disclosed reserves dispersion and firm risk, the stock price and bid-ask spread reactions to the reserves dispersion disclosure, and whether the dispersion amounts are affected by opportunism. Section 7 concludes.

II. INSTITUTIONAL BACKGROUND, RELATED RESEARCH, AND BASIS FOR EXPECTED RELATIONS

Institutional Background

O&G reserves is the main asset of O&G firms—for our sample firms, the carrying amount of reserves averages 80% of total assets. However, the carrying amount of this asset is determined using modified historical cost, where historical cost is the aggregated capitalized costs of exploration and development activities.[3] The value of the reserves can differ from its carrying amount for several reasons. First, exploration costs are not necessarily indicative of the value of the discovered reserves because the costs depend on exploration ability and location idiosyncrasies. Second, development costs are subject to unanticipated geological and technical conditions that also are not necessarily indicative of the value of the reserves being developed.

[3] Canadian firms capitalized these costs using successful efforts or full cost accounting. Under successful efforts accounting firms capitalize exploration and development costs associated with successful exploration; under full cost accounting costs of unsuccessful exploration generally are allocated to reserves resulting from successful exploration. Although neither method attempts to measure the value of the reserves, both are subject to impairment testing. Only 34 of our 1,156 sample firm-year observations use successful efforts accounting.

Third, external factors and firm-specific business circumstances can affect the value of the reserves differently from the carrying amount.[4]

Likely because of the potential for a sizable difference between the value of recoverable reserves and its carrying amount, and the risk relating to its viable recoverability, securities regulators require additional disclosures relating to the value, and risk, of the reserves. Presumably, these regulators believe such disclosures enhance investors' ability to make informed assessments about equity and debt values of O&G firms and, thus, to make more informed investment decisions. In Canada, the Alberta Securities Commission's (ASC) rule NI 51-101 specifies these rules.[5]

O&G firms disclose information regarding their recoverable reserves in physical and monetary units. To construct this information, firms first obtain geological probability estimates of the volume of O&G resources in physical units. The volume of resources has variation largely because volume estimates depend on sampling techniques and assessments of unobservable underground geological conditions. Firms then determine whether this estimated volume is economically viable to extract. In making this determination, firms consider expected extraction costs, i.e., operating, development, abandonment, and other costs, and expected future O&G prices. Reserves do not include resources that are not economically viable to extract.

Firms typically convert reserves determined in physical units into monetary units using a discounted cash flow model based on expectations about the schedule of future extraction of the reserves, O&G market prices, and extraction costs. Expected O&G prices, cost inflation rates,

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[4] Examples include discoveries of shale gas in the US and oil sands in Canada, new techniques for deep-water drilling, the Gulf of Mexico extraction moratorium, increasing differences between Brent and West Texas Intermediate reference prices associated with excess oil supply in the US, and decoupling of gas and oil prices.

[5] ASC states that NI 51-101 is intended "to enhance the quality, consistency, timeliness and comparability of public disclosure by reporting issuers concerning their upstream O&G activities…" and that NI 51-101 was "a response to concerns expressed by market participants about the quality and consistency of public O&G disclosure" (Canadian Securities Administrators Notice, September 26th 2003).

and currency exchange rates must be within the range of forecasts made by independent qualified reserves evaluators or auditors.[6] The evaluators typically forecast O&G prices for the next three years based on futures prices for West Texas Intermediate (WTI) oil and for subsequent years based on assumptions of supply and demand, industry mergers and acquisitions activity, and oil- and gas-specific price inflation rates.[7] These forecast prices and costs are single amounts for each future period. Firms are required to use a 10% interest rate to discount these cash flow expectations.[8]

In Canada, as in the US, publicly listed O&G firms are required to disclose proved reserves, which corresponds to the bottom decile of the probability distribution of the reserves. That is, proved reserves has a probability of being recovered of at least 90% and is referred to as P10.[9] Beginning in 2003, NI 51-101 requires Canadian O&G firms also to disclose proved plus probable reserves, which corresponds to the median of the distribution. That is, proved plus probable reserves has a probability of being recovered of at least 50% and is referred to as P50. P50 represents the best estimate of reserves (Canadian Oil and Gas Evaluation Handbook (COGEH), 2002; 2007). Prior to 2003, only firms headquartered in particular Canadian states or engaged in initial or seasoned public equity offerings were required to disclose both P10 and P50. NI 51-101 specifies how to determine P10 and P50, including requiring the use of external evaluators, and expands the information about reserves firms must disclose. Appendix A

[6] NI 51-101 defines expected prices and extraction costs as "generally recognized as being a reasonable outlook on the future." Section 4.1 of the Companion Policy explains that future prices or costs outside the range of forecasts, as of the same date and for the same future period, by independent qualified reserves evaluators or auditors would not satisfy this requirement. If a firm has forward contracts for physical delivery of oil or gas, the forward price is used for the contracted volume and date.

[7] We thank Gary Finnis from Sproule & Associates for explaining this process to us.

[8] Because only reserves estimates calculated using a 10% discount rate are externally evaluated, we use them in our tests. However, firms also must disclose unaudited undiscounted reserves estimates, and some firms disclose reserve estimates based on other discount rates, e.g., 5% and 15%.

[9] Proved reserves also is referred to as P90 in reference to the inverse cumulative distribution function. Both P10 and P90 refer to reserves, X*, such that the probability of $X > X^* = 90\%$, where X is recoverable reserves.

provides an example of the reserves disclosures on Form 51-101F1, the Statement of Reserves Data and Other Information. Firms traded on the Toronto Stock Exchange, TSX (Toronto Stock Venture Exchange, TSX-V), must file Form 51-101F1 90 (120) days after fiscal year-end.

Figure 1 illustrates P10 and P50 in terms of the probability distribution of O&G reserves. Figure 1 shows how P50 minus P10 provides a measure of the dispersion of the reserves distribution. This dispersion stems from risk relating to the volume of O&G that is economically viable to extract, given expected O&G prices and extraction costs. The reserves probability threshold amounts do not incorporate variability in future prices and costs. Appendix B shows how (P50 – P10)/P50, which is our measure of reserves dispersion, is a monotonic transformation of the standard deviation of the reserves distribution, assuming reserves is lognormally distributed.[10]

Prior to 2010, the SEC prohibited US firms from disclosing P50. In its proposing release relating to this rule change, the SEC explains that its concern relates to potential manipulation of and estimation error in disclosed P50, and several comment letters on the proposing release echo this concern.[11] Recent scandals around O&G reserves disclosures suggest that this could occur.[12]

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[10] Appendix B shows that P10 and P50 are sufficient to infer the variance of a lognormal distribution. O&G reserves are presumed to have a lognormal distribution because reserves measure volume, i.e., the product of the height, width, and depth of the deposit, and the product of random variables converges to a lognormal distribution (Drew 1990). Empirical studies based on O&G reserves provide evidence supporting this distributional assumption (American Association of Petroleum Geologists Committee 1999; Robinson and Elliott 2005; Attanasi and Charpentier 2007). Even if the distribution is not lognormal, (P50 – P10) / P50 is monotonically positively related to the variance if the distribution is unimodal (Bickel and Lehmann, 1979). Although a multimodal distribution other than lognormal is possible, it is unclear why such a distribution would be more descriptive of O&G reserves, and we are unaware of any empirical study that suggests a multimodal distribution is descriptive.

[11] For example, the SEC explains the disclosure prohibition by stating "imaginative promoters will try to convince investors to invest in speculative ventures while misleading them as to the true risks involved. Those who would mislead the public can easily abuse reporting of tonnage and grade for geologically-inferred mineralization" (Baer 2001). Commenters on the proposing release also expressed concern that "the inherent uncertainty associated with such reserves estimates may lead to investor confusion and misunderstanding" and that "the broad range of technologies and methods used by companies to support these estimates would lead to inconsistent disclosure among companies" (as cited in U.S. Securities and Exchange Commission 2008, p. 62).

[12] More than twenty recent high-profile lawsuits occurred in the US related to reserves disclosures, with settlements of up to $450 million in the case of Shell Oil. In addition, on June 25, 2011 the New York Times, based on

However, comment letters from investors, among others, urged the SEC to allow the disclosure.[13] Several O&G firms opposed mandatory disclosure of probable reserves by alleging that such disclosure would increase litigation risk. The final rule allows US O&G firms to disclose P50 using a definition of P50 virtually identical to the Canadian definition (SEC 2008). The opposition by O&G firms to mandatory disclosure of probable reserves and that fewer than 10% of US O&G firms voluntarily disclose this amount during our sample period are consistent with firms considering probable reserves to be proprietary information. These facts suggest it is unlikely that investors have private access to P50.

Related Research

Our study contributes to three streams of research—those related to disclosures that provide information about firm risk, fair value estimates, and O&G reserves. Regarding disclosures that provide information related to firm risk, several studies examine whether the sensitivity measures for financial instruments and derivatives explain systematic risk, e.g., beta, cost of capital, and valuation multiples. Some studies examine the relevance of disclosures of firms' sensitivity to interest rate risk (Hodder 2002) and exchange rate risk (Sribunnak and Wong 2004). Others examine disclosures of Value-at-Risk (VaR), which is the potential loss on a portfolio of financial instruments over a given period with a specified probability, usually 5%. Jorian (2002) and Liu, Ryan, and Tan (2004) examine the risk-relevance of VaR estimates for

hundreds of industry emails, internal documents, and research analyst reports, alleged aggressive reserves reporting by exploration and production firms with natural gas unconventional shale resources.

[13] Standard and Poor's comment letter states "we believe that disclosure of probable reserves provides forward-looking information that is critical to the analysis of E&P companies…We believe that permitting disclosure of unproved reserves in public filings will make them more consistent over time…With appropriate disclosure, analysts and others will understand the greater uncertainties of early-stage reserve development" (https://www.sec.gov/comments/s7-29-07/s72907-67.pdf). Other comment letters state that the disclosure of probable reserves would provide a more complete picture of a firm's full portfolio of opportunities (e.g., letters from CFA Institute, Chesapeake, Deloitte, EnCana, Evolution, McMoRan, Newfield, Petrobras, Petro-Canada, Questar, Ryder Scott, Sasol, Ryder Scott, Shell, SPE, Three Senators, Wagner, and Zakaib).

banks and find that the estimates explain variances of trading income, stock returns, and beta. However, Perignon and Smith (2010) questions VaR estimates' ability to have an association with risk because historical, not forward-looking, information underlies the estimates. Relating to O&G firms, Rajgopal (1999) and Thornton and Welker (2004) find that commodity price sensitivity disclosures provide risk-relevant information. Overall, the evidence on the risk-relevance of market risk disclosures is inconclusive (see Ryan 1997; 2012). Potential explanations for these inconclusive results are lack of comparability, cognitive biases associated with particular disclosure formats (Hodder, Koonce, and McAnally 2001; Koonce, McAnally, and Mercer 2005; Nelson and Rupar 2015), and limited sample sizes.

Our setting likely permits more powerful tests of risk disclosure informativeness because dispersion in O&G reserves is closely related to dispersion in O&G firms' future cash flows. In addition, the disclosures differ from the market risk and VaR disclosures studied in prior research. Whereas those studies focus on disclosures relating to the sensitivity of financial instruments' fair values to observable market prices, e.g., interest rate risk and currency risk, we focus on the probability distribution of the value of a non-financial asset. Investors and other outsiders can obtain information about financial market risks from sources other than the firm. Because the estimation of reserves requires not only technical knowledge, but also considerable firm-specific information, reserves risk likely is known only to the firm and, thus, it is likely that disclosure of this risk is the source of this information to investors.

Our study also relates to the literature on fair value accounting. There is concern that fair value estimates are fraught with estimation error, including possible bias, which diminishes their potential informativeness. Thus, many studies focus on the relevance of, and estimation error associated with, fair value disclosures (e.g., Muller and Riedl 2002; Plantin, Sapra, and Shin

2008; Ryan 2008; Kolev 2009; Barth and Taylor 2010; Khan 2010; Kothari, Ramanna, and Skinner 2010; Laux and Leuz 2010; Lev and Zhou 2010; Song, Thomas, and Yi 2010; Riedl and Serafeim 2011; Goh, Li, Ng, and Yong 2015). Fewer studies examine the quantification of risk associated with the assets' underlying values, which are the object of the fair value estimates. Those that do generally focus on the financial industry (e.g., Hodder, Hopkins, and Wahlen 2006; Blankespoor, Linsmeier, Petroni, and Shakespeare 2013). To our knowledge, ours is the first study to examine the risk-relevance of disclosures relating to the underlying value of a primary non-financial operating asset, such as O&G reserves. Our findings suggest that quantitative measures of asset value dispersion could aid investors in assessing the variability in firms' future performance.

Regarding disclosures of O&G reserves, several studies examine whether disclosed reserves value estimates are more value-relevant than recognized O&G assets, which are based on historical cost (e.g., Magliolo 1986; Harris and Ohlson 1987, 1990; Clinch and Magliolo 1992; Boone 2002; Patatoukas, Sloan, and Zha 2015). Because the samples in these studies comprise US O&G firms, they focus on disclosed proved reserves, i.e., P10. As section 2.1 explains, disclosed proved plus probable reserves, i.e., P50, and thus the information about reserves dispersion reflected in the difference between P50 and P10, is required disclosure only for Canadian O&G firms since the ASC introduced NI 51-101 in 2003. This information about reserves dispersion is the focus of our study.

III. SAMPLE AND DATA

Our sample comprises publicly traded Canadian O&G firms from 2004 to 2011. We begin our sample in 2004 because disclosure of proved plus probable reserves, P50—the focus of our analysis—became mandatory in Canada in 2003, and some of our tests require beginning-of-

year reserves. We obtain most of our reserves data from the CanOils Database Ltd. (hereafter CanOils), which is the leading commercial database for Canadian O&G exploration and production firms. 2011 is the last year of data available to us. CanOils contains data obtained from financial statements and reserves disclosures for O&G firms listed on the TSX and the TSX-V, including the filing dates of Form 51-101F1. We obtain stock price and bid-ask spread data from Datastream for firms traded on TSX and from TSX Venture Summary Trading Files for firms traded on TSX-V.[14] We obtain information on technical revisions to reserves estimates and evaluators from the database that the ASC uses for its enforcement activity and the analysis of technical revisions summarized in its O&G annual review (e.g., ASC 2008).[15] If data are not available in the CanOils and ASC databases, we hand-collect them from firm's reports filed in the System for Electronic Document Analysis and Retrieval.

We begin our sample construction using the 1,970 firm-year observations from O&G firms listed on the TSX or TSX-V between 2004 and 2011. The TSX and TSX-V list the most O&G firms in the world, which is consistent with O&G being a key Canadian industry. In Canada, O&G production accounts for more than 7% of GDP; it is 2.5% in the US. We eliminate observations from firms that are not primarily O&G producers, i.e., integrated oil firms and exploration and production firms with more than 5% of revenue from sources other than O&G exploration-production activities, such as real estate, drilling, marketing, and midstream and refining services. This is because their firm values might be related to factors other than O&G reserves, which could confound our results. We eliminate observations without reserves

[14] We obtain stock split data from TSX Venture Listed Company Contacts, a TMX Group database that provides monthly outstanding shares, combined with the split dates from CanOils. We obtain dividend data by using Python to extract the ex-dividend date, currency, and dividend amount from daily publications from the Toronto Stock Exchange (http://www.tmx.com/en/listings/products_services/ir_data_solution/venture_market_information.html). We thank Jill Scullion from TMX group for suggesting this approach for obtaining the dividend data.

[15] Technical revisions are annual changes in reserves estimates—for properties owned by the firm at the start of the year by type of O&G product and measured in physical units—as the result of new technical information.

data at the beginning of the year because some of our tests require annual change in reserves. These data requirements result in a sample of 1,156 firm-year observations from 258 firms.[16]

IV. FIRM RISK AND RESERVES DISPERSION

Equity Volatility

To determine whether disclosed information about reserves dispersion reflects information regarding the variation in O&G reserves and, thus, firm risk, we first test whether the dispersion is associated with future equity volatility. Specifically, we estimate equation (1).

$$Log\_Future\_Volatility = \delta_0 + \delta_1\, Reserves\_Dispersion_t + \phi_1\, General\_Controls_t + \phi_2\, O\&G\_Controls_t + \varepsilon_t \quad (1)$$

Log_Future_Volatility is logarithm of the standard deviation of daily stock returns, in %, over the 365 days following the disclosure of reserves information, i.e., the filing of Form 51-101F1. The focus of our tests is *Reserves_Dispersion*, the difference between proved reserves and proved plus probable reserves, scaled by proved plus probable reserves, i.e., (P50 – P10) / P50. If the disclosed information about reserves dispersion is positively associated with future equity volatility, we expect δ_1 is positive.

General_Controls comprises control variables prior research finds are associated with equity risk. They are *Size*, logarithm of end-of-year equity market value (Banz 1981; Fama and French 1992); *BM*, end-of-year equity book-to-market ratio (Fama and French 1992), *Leverage*, ratio of total liabilities to total assets (Beaver, McNichols, and Rhie 2005); *ROA*, return on assets, i.e., earnings before extraordinary items divided by total assets (Beaver et al. 2005); *Past_Return*, daily stock return compounded over 365 days before fiscal year-end (Jegadeesh

[16] Our sample of 258 firms compares favorably with those in related prior research. For example, the sample in Clinch and Magliolo (1992) comprises 86 firms, and that in Patatoukas et al. (2015) comprises 21 firms.

and Titman 1993; Carhart 1997); and *Log_Bidask*, logarithm of average daily bid-ask spread over 365 days before fiscal year-end (Christoffersen, Goyenko, Jacobs, and Karoui 2014).

O&G_Controls comprises control variables specific to the O&G industry, including several related to reserves disclosed with P10 and P50. We include these variables as controls for reserves characteristics and because the enhanced monitoring requirements of NI 51-101 could have resulted in increased association between these characteristics and firm risk. *Log_Reserves_Median* is the logarithm of P50. *Contingent_Reserves* is O&G resources, in dollars, that currently are not economically viable to extract, scaled by P50. *Undeveloped_Reserves* is undeveloped reserves, i.e., reserves for which wells have not been completed or drilled to a point that permits production of commercial quantities of O&G, *Discoveries* is exploration discoveries and extensions, plus reserves discovered in prior years that become economically viable in the current year, *Acquisitions* is reserves acquisitions, *Dispositions* is reserves dispositions, *Production* is production volume, *Recoveries* is improved recoveries and infill drillings, and *Revisions* is revisions of previously disclosed reserves. We measure these variables in BOEs, scaled by P50 in BOEs, because firms do not disclose the corresponding dollar amounts.

The other *O&G_Controls* are *Percent_NatGas*, *Derivatives*, and *Investment*, which could explain cross-sectional differences in risk associated with reserves. *Percent_NatGas* is the proportion of proved reserves in BOE that are natural gas, which we include as a control for differences between oil and gas in the relation between firm risk and reserves dispersion. *Derivatives* is an indicator variable that equals one if the firm has any nonzero asset or liability related to financial gains or losses of derivative instruments classified as financial instruments, and zero otherwise. We include *Derivatives* as a control for firms' financial derivatives

contracts, which are not considered when determining reserves but can affect firm risk.[17] *Investment* is capital expenditures, scaled by total assets, which we include as a control for differences in firms' expansion activities. We also include the lag of *Log_Future_Volatility* to mitigate potential confounding effects of unidentified firm characteristics that are correlated with *Reserves_Dispersion* and stock return volatility (Weber 2006; Cheng, Dhaliwal, and Neamtiu 2011).[18]

Equation (1) also includes year and firm fixed effects as controls for macroeconomic conditions and time invariant firm characteristics. *t* denotes year, and firm subscripts are omitted. In equation (1) and all subsequent analyses of firm risk, we construct *t*-statistics using standard errors clustered by firm and year (Gow, Ormazabal, and Taylor 2010).[19]

Table 1 provides descriptive statistics for the variables we use to relate reserves dispersion and firm risk. Table 1 reveals that O&G reserves exhibit considerable dispersion; the mean (median) of *Reserves_Dispersion* is 36% (32%) of total proved plus probable reserves. *Reserves_Dispersion* also exhibits substantial variation (Std = 18%). Untabulated statistics reveal that the mean of probable reserves, i.e., P50 minus P10, is $239 million, which is 61% of average total assets and 96% of average market value of equity. Untabulated statistics also reveal that mean P50 is $798 million, which is approximately 153% of total assets and 225% of market value of equity. These statistics reveal that reserves are economically significant assets

[17] Untabulated findings reveal that our inferences are unaffected by defining *Derivatives* as the sum of the absolute values of the fair values of derivative instruments, scaled by total assets.

[18] To construct lagged *Log_Future_Volatility*, we use stock returns in the 365 days before the current year reserves disclosure, rather than 365 days after the prior year disclosure, to avoid overlapping windows resulting from year-to-year differences in the disclosure dates.

[19] To mitigate the possibility that our inferences are affected by outliers we use logarithms of variables that are not ratios and have only non-negative values, and winsorize other variables at the 1% and 99% of their pooled distributions. In addition, in all tests we eliminate observations with studentized residuals greater than three. To ensure the small number of time clusters does not affect our *t*-statistics we bootstrap double-clustered standard errors with 500 iterations. The resulting *t*-statistics are very similar to those we tabulate.

of O&G firms, and that the estimated dispersion of reserves is substantial. Table 1 also reveals that mean (median) *Log_Future_Volatility* is 1.58 (1.59). In unlogged terms, mean (median) annualized volatility is 96% (78%).[20]

Regarding *General_Controls*, table 1 reveals that mean (median) *Size* is 4.26 (4.22), which corresponds to an average equity market value of $665 million in unlogged terms. Although mean *BM* is greater than one, 1.23, the median is 0.68, which is consistent with the book value of equity not reflecting fully the value of a major asset of O&G firms, namely reserves. Mean and median *ROA* are −0.12 and −0.03, which indicate that losses are common. Although mean *Past_Return* is positive, 0.30, the median is negative, −0.07, which indicates that more than half of the firms have negative returns.

Regarding *O&G_Controls*, table 1 reveals that mean *Undeveloped Reserves* and *Contingent_Reserves* are 0.16 and 0.71, which indicate that the averages of undeveloped reserves and contingent reserves are 16% and 71% of P50. Mean *Discoveries*, *Acquisitions*, *Dispositions*, *Production*, *Recoveries*, and *Revisions* are 0.21, 0.10, 0.06, 0.10, 0.01, and –0.09, which indicate that, on average, they are 21%, 10%, 6%, 10%, 1%, and 9% of P50 in BOEs. Mean *Percent_NatGas* of 0.56, *Derivatives* of 0.40, and *Investment* of 0.30 indicate that on average 56% of proved reserves are natural gas, 40% of firms have financial derivatives, and capital expenditures are 30% of total assets.

Table 2 presents regression summary statistics from estimating five versions of equation (1), which sequentially include sets of control variables and year and firm fixed effects. Most

[20] This volatility is higher than untabulated mean (median) volatility of US O&G firms of 55 % (47%). This difference is attributable to the greater presence of young and small firms in our sample, such as those listed in TSX-V, which are less liquid than US O&G firms. Ignoring TSX-V-listed firms, the untabulated mean (median) of volatility is 61% (52%), which is closer to that of US O&G firms. Untabulated statistics also reveal that the high average bid-ask spread, *Log_Bidask*, is attributable to firms listed on TSX-V.

importantly, table 2 reveals that in all five versions the coefficient on *Reserves_Dispersion* is significantly positive as expected (*t*-stats. range from 2.68 to 5.59). These findings indicate that the disclosed information about reserves dispersion is significantly positively associated with firm risk, as measured by future total equity volatility. In addition, table 2 reveals that *Reserve_Dispersion*'s coefficient ranges from 0.17 to 0.57, which indicates that *Reserves_Dispersion* is associated with economically meaningful variation in future volatility. The 0.17 coefficient estimate indicates that a one standard deviation change in *Reserves_Dispersion*, i.e., 0.18, corresponds to 0.03 higher *Log_Future_Volatility*, which in unlogged and annualized terms is approximately 16% of future volatility.[21]

Table 2 also reveals that several control variables are significantly associated with future equity volatility, although which ones and how depends on which control variables we include in the estimation equation. Most notably, the coefficients on *Size*, *BM*, *Leverage*, *Log_Reserves_Median*, *Undeveloped_Reserves*, *Dispositions*, *Derivatives*, and *Lag_Dep_Variable*, are consistently significantly different from zero when we do not include firm fixed effects. However, only the coefficients on *Leverage*, *Log_Bidask*, and *Undeveloped_Reserves* are significantly different from zero when we include firm fixed effects (*t*-stats. = 1.71, 2.13, and –3.62).

Systematic Risk, Idiosyncratic Risk, and Credit Risk

To provide additional insights into the association between *Reserves_Dispersion* and firm risk, in equation (1) we replace *Log_Future_Volatility* with three alternative risk measures. The first is systematic equity risk, *Future_Beta*, the slope coefficient from a regression of daily stock returns in excess of the risk-free rate over the 365 days following the reserves disclosure on daily

[21] Untabulated findings based on estimating equation (1) including the annual returns on, and volatility in, WTI oil and Henry Hub gas indices and omitting year fixed effects reveal the same inferences as revealed by table 2.

market returns in excess of the risk-free rate. The second is idiosyncratic equity volatility, *Log_Future_Idiosyn*, the logarithm of the standard deviation of the residuals from the market model regression. The third is credit risk, *Future_Interest*, the subsequent year' net interest expense scaled by average beginning- and end-of-year debt minus cash.

The dispersion disclosures can provide information about systematic risk by reflecting the firm's ability to adjust to future market demand or price trends; O&G firms generally are price-takers. That is, the amount of reserves depends not only on the physical characteristics of the underlying deposits, but also on market conditions, particularly the price of O&G.[22] Consequently, changes in market conditions affect differently firms with the same P50 but different dispersion. In particular, future market conditions likely affect firms with higher dispersion more because their reserves are less certain, i.e., P10 is lower, and therefore are more likely to require greater future development and investment. The dispersion disclosures also can provide information about idiosyncratic risk by reflecting the risk inherent in the firm's O&G properties. Recent finance literature suggests idiosyncratic risk is priced and is likely to matter to investors who cannot diversify their investment in the firm, e.g., executives receiving performance-based pay and owners of family-held firms (e.g., Merton 1987; Johnson 2004; Ang, Hodrick, Xing, and Zhang 2006; Goyal and Santa-Clara 2003; Bali, Cakici, Yan, and Zhang 2005). The dispersion disclosures can provide information about credit risk because higher risk means higher frequency of negative outcomes and, thus, higher risk of debt default.

Table 1 reveals that mean (median) *Future_Beta* is 1.15 (1.19), which indicates that O&G firms have more than average sensitivity to changes in market conditions. Mean (median)

[22] Untabulated statistics reveal that *Contingent_Reserves* is negatively correlated with O&G prices, which indicates that the amount of non-viable resources—and, accordingly, viable resources, i.e., reserves—is sensitive to market conditions.

Log_Future_Idiosyn is 1.51 (1.53), which, when compared to mean (median) *Log_Future_Volatility*, indicates that most future volatility is attributable to idiosyncratic risk. Mean (median) value of *Future_Interest* is 0.06 (0.05), which indicates an average interest rate of 6% (5%) of net debt.

Table 3 presents summary statistics from estimating versions of equation (1) analogous to those in table 2, in panels A, B, and C for *Future_Beta*, *Log_Future_Idiosyn*, and *Future_Interest*. For the sake of parsimony, table 3 does not tabulate control variable coefficients. Panel A reveals that disclosed reserves dispersion is significantly positively associated with systematic risk, *Future_Beta*. The coefficient on *Reserves_Dispersion* is significantly positive in all five columns (*t*-stats. range from 2.33 to 4.91).[23] Panel B reveals the same inferences relating to future idiosyncratic volatility, *Log_Future_Idiosyn* (*t*-stats. range from 2.28 to 5.59). Panel C reveals that the disclosed reserves dispersion is significantly positively associated with not only equity risk, but also credit risk, *Future_Interest*. In particular, the coefficient on *Reserves_Dispersion* is significantly positive in all versions of equation (1) (*t*-stats. range from 2.79 to 4.36). These findings suggest that the disclosed reserves dispersion also can inform debt contracting.

[23] Although these statistics indicate that *Reserves_Dispersion* is positively associated with cost of capital, prior research criticizes the use of beta to measure cost of capital (e.g., Fama and French 1992). Lack of analyst forecast data precludes us from using measures of implied cost of capital (e.g., Gebhardt, Lee, and Swaminathan 2001). Instead, we estimate equation (1) alternatively using as cost of capital proxies future realized stock returns, *Future Return*, and book-to-price and earnings-to-price ratios, *BP* and *EP*, where *Future Return* is stock return compounded over one year after the reserves disclosure. Untabulated findings reveal a positive association between *Reserves_Dispersion* and *BP* and *Future Return*, but only the relation with *BP* is significant (*t*-stats. = 3.52 and 0.86), and a significantly negative association between *Reserves_Dispersion* and *EP* (*t*-stat. = –5.30). Although the insignificant relation with *Future Return* is not surprising (e.g., Elton 1999; Fama and French 2002), the negative *EP* association seems contrary to our expectation. However, Penman and Reggiani (2013) explains that such a finding could be attributable to accounting conservatism, which results in later recognition of riskier earnings. Consistent with this explanation, untabulated statistics reveal that firms with lower *EP* exhibit more positive future earnings changes, not negative, and a significantly positive relation between *Reserves_Dispersion* and (*Future Return* – E/P_{t+1}) (*t*-stat. = 4.23), which Penman and Zhu (2011) identifies as a proxy for cost of capital that isolates the risky growth component of the discount rate.

Alternative Measures of O&G Reserves

We next estimate equation (1) replacing *Reserves_Dispersion* with reserves dispersion measured in BOEs, *Reserves_Dispersion_Q*, which mitigates effects on our inferences of variation in O&G prices. Table 1 reveals that mean (median) *Reserves_Dispersion_Q* is 0.41 (0.37), which is somewhat higher than that of *Reserves_Dispersion* of 0.36 (0.32). Untabulated statistics reveal that the Pearson correlation between *Reserves_Dispersion_Q* and *Reserves_Dispersion* is 0.87. This high correlation is not surprising given the limited role O&G prices have in determining reserves in dollars, as discussed in section 2.

Table 4 presents the findings. Panel A (B) presents statistics for *Log_Future_Volatility* (*Future_Beta*, *Log_Future_Idiosyn*, and *Log_Future_Interest*) analogous to those in table 2 (table 3). For the sake of parsimony, we do not tabulate control variable coefficients and in panel B we present only the version of equation (1) that includes all control variables. The findings in both panels reveal the same inferences as revealed by the findings in tables 2 and 3. In panel A, the *Reserves_Dispersion_Q* coefficient is significantly positive in all five versions of equation (1) (*t*-stats. range from 3.83 to 6.24), and in panel B, the *Reserves_Dispersion_Q* coefficient is significantly positive in all three (*t*-stats. range from 3.58 to 4.48).

Taken together, the findings in table 4 mitigate concern that our inferences could be attributable to differences across firms in O&G price forecasts or other valuation assumptions used in the estimation of dollar reserves. The findings also mitigate the concern that hedging of O&G prices could affect our inferences from tables 2 and 3 because *Derivatives* does not effectively control for hedging effects of financial derivatives.[24]

[24] Our tabulated findings are based on pre-tax reserves, which are audited, but firms also disclose after-tax reserves (see Appendix A for an example), which are not. Thus, in untabulated estimations of equation (1), we use after-tax reserves. In addition, because trusts have more advantageous tax treatment than corporations, in untabulated estimations of equation (1), we include an indicator variable that equals one if the firm is a trust, and zero otherwise.

Supplemental Risk Disclosures, Financial Distress, and Managerial Opportunism

Other disclosures that enable investors to construct alternative measures of risk could affect our inferences relating to *Reserves_Dispersion*. Thus, we construct a measure of exploration risk, *Risk_Other_Info*, and include it as a control variable in equation (1). Following Sunder (1976) and Rajgopal and Shevlin (2002), *Risk_Other_Info* is the variance of expected future operating cash flows from exploration activity in year *t*, $x^2LN\theta(1-\theta)$, scaled by its mean, $xLN\theta - Nc$. L is the weighted average estimated remaining life of the firm's wells, N is the number of net exploratory wells drilled in year *t*, θ is the probability exploratory wells yield exploitable reserves, c is exploration cost per well, and x is the present value of cash flows per successful well. Table 5, columns (1) and (2), presents the findings. It reveals that *Risk_Other_Info* is significantly positively (insignificantly) related to *Log_Future_Volatility* in the absence (presence) of other control variables (*t*-stats. = 3.85 and 0.16). Regardless, the *Reserves_Dispersion* coefficient is significantly positive (*t*-stats. = 3.45 and 4.46).

Our inferences relating to *Reserves_Dispersion* also could be affected by firms experiencing financial distress, which could be why mean equity book-to-market ratio, *BM*, exceeds one, and mean and median return on assets, *ROA*, are negative. As a firm approaches debt default, the volatility of equity payoffs increases because of the convexity of equity value, regardless of changes in the volatility of the firm's assets. Thus, following Bharath and Shumway (2008), we include in equation (1) *Distance to Default*, which is N(–*DD*), where N is the standard normal distribution and *DD* is the distance to default. $DD = \frac{ln\left(\frac{E+D}{D}\right)+(r_{i,t-1}-0.5\sigma_A{}^2)T}{\sigma_A\sqrt{T}}$, where E is market value of equity, D is carrying amount of debt, σ_A is implied unlevered

The findings from both sets of untabulated analyses reveal the coefficient on *Reserves_Dispersion* is significantly positive in all versions of equation (1) analogous to those we tabulate.

volatility, $r_{i,t\text{-}1}$ is stock return over the previous year, and T is the one-year forecasting horizon. Table 5, columns (3) and (4), presents the findings. It reveals that although *Distance to Default* and *Log_Future_Volatility* are significantly positively related (*t*-stats. = 8.60 and 1.82), our inferences regarding *Reserves_Dispersion* are unaffected (*t*-stats. = 5.42 and 2.80).[25]

It also is possible that managers of poorly governed firms opportunistically manipulate reserves upwards. Thus, we include in equation (1) additional control variables that reflect disclosure incentives and governance characteristics. *Disclosure Incentives* comprises four variables prior research uses as proxies for managerial incentives for opportunistic disclosures, *Negative_FCF*, *Impairment*, *Losses*, and *Equity_Compensation* (e.g., Livnat and Tan 2004; Armstrong, Larcker, Ormazabal, and Taylor 2013). *Negative_FCF* is an indicator variable that equals one if free cash flow, i.e., the sum of cash from operating and investing activities, is negative, and zero otherwise. *Impairment* is write-downs of O&G assets, scaled by the carrying amount of reserves. Because carrying amounts larger than P50 trigger impairment tests, inflating reserves could avoid recognizing an impairment. *Losses* is an indicator variable that equals one if earnings is negative, and zero otherwise. *Equity_Compensation* is the logarithm of one plus stock-based compensation expense. If upwards management of probable reserves is associated with these disclosure incentives, we expect the coefficients on *Negative_FCF*, *Impairment*, *Losses*, and *Equity_Compensation* are positive.

[25] We also estimate equation (1) using *Log_Future_UnlevVol* instead of *Log_Future_Volatility* to mitigate leverage's effect on equity volatility. We follow Bharath and Shumway (2008) and estimate unlevered volatility as the logarithm of $UnlevVol = \frac{E}{E+D}\sigma_E + \frac{D}{E+D}(0.05 + 0.025\sigma_E)$, where σ_E is the standard deviation of daily equity returns over the 365 days before the reserves disclosure. Untabulated findings reveal a positive significant coefficient on *Reserves_Dispersion* in all versions of equation (1). To mitigate the effects on our inferences of distressed firms, we also estimate equation (1) including only observations with above (below) median *ROA* (*BM*). For observations in this analysis, mean (median) *ROA* is 0.50 (0.30) and mean (median) *BM* is 0.47 (0.40). Untabulated findings reveal a significantly positive coefficient on *Reserves_Dispersion* for both groups of firms.

Because effective governance can curb opportunistic behavior, we also include *Governance Characteristics*, which comprises three variables that reflect monitoring of reserves disclosures, *Reserves_Committee*, *Big4*, and *Top_Evaluator*. *Reserves_Committee* is an indicator variable that equals one if the firm has a reserves committee, and zero otherwise. *Big4* is an indicator variable that equals one if the firm uses a Big 4 auditor, i.e., Deloitte, EY, KPMG, and PwC, and zero otherwise. *Top_Evaluator* is an indicator variable that equals one if the evaluator of reserves is one of the top Canadian evaluators in terms of market share, and zero otherwise; the top evaluators are identified by the ASC.[26] We expect increased monitoring by reserves committees, Big 4 auditors, and top evaluators to reduce firms' ability to manage reserves upward. If upwards management of the probable reserves is associated with these governance characteristics, we expect the coefficients on *Reserves_Committee*, *Big4*, and *Top_Evaluator* are negative.

Table 1 presents descriptive statistics for the *Disclosure Incentives* and *Governance Characteristics* variables. Regarding disclosure incentives, table 1 reveals that mean *Negative_FCF* is 0.78, which indicates that 78% of firms have negative free cash flow, and mean *Losses* is 0.63, which indicates that 63% exhibit losses. These statistics are consistent with small and growing firms investing heavily in exploration and development activities. Table 1 also reveals that mean *Equity_Compensation* is 6.08, which corresponds to an average stock-based compensation expense of $440,000, i.e., approximately 1.8% of average earnings. Mean *Impairment* is 0.06, which indicates the average of recognized impairments of O&G assets is 6% of the carrying amount of the reserves. Regarding governance characteristics, table 1 reveals that

[26] The top evaluators are AJM Petroleum Consultants, Chapman Petroleum Engineering, Degolyer & MacNaughton, GLJ Petroleum Consultants & Associates, McDaniel & Associates Consultants, Paddock Lindstrom & Associates, and Sproule & Associates.

means of *Reserves_Committee*, *Big4*, and *Top_Evaluator* are 0.77, 0.73, and 0.80, which indicate that approximately 77% of the firms have a reserves committee, 73% have a Big 4 auditor, and 80% have their reserves evaluated by one of the top evaluators.[27]

Table 5, columns (5) and (6), presents the findings. It reveals that several of the coefficients on *Disclosure Incentives* and *Governance Characteristics* are consistent with expectations. For example, in column (6), which includes all of the control variables in table 2, the coefficients on *Negative_FCF*, *Losses*, and *Equity_Compensation* are positive, and that on *Losses* is significantly so (*t*-stats. = 1.27, 4.41, and 0.66). Although the coefficients on *Reserves_Committee* and *Big4* are negative, they are not significantly different from zero (*t*-stats. = –1.31 and –1.15). The coefficients on *Impairment* and *Top_Evaluator* have unexpected signs, but are not significantly different from zero. More importantly, table 5 reveals that our inferences regarding *Reserves_Dispersion* are unaffected by including the disclosure incentives and governance characteristics variables (*t*-stats. = 5.71 and 4.51).

Additional Risk Analyses

An alternative explanation of our findings in tables 2 and 3 is that reserves disclosures confuse investors, which increases return volatility, rather than provide information about firm risk. If this is the case, the increased volatility associated with the disclosure would dissipate as the market learns that the disclosure did not convey risk information. Thus, we construct our three volatility-based measures of risk, *Log_Future_Volatility*, *Future_Beta*, and *Log_Future_Idiosyn*, excluding the period immediately after the disclosure. Because we have no expectation regarding how long any investor confusion lasts, we construct these measures

[27] Untabulated univariate correlations between several of these variables are significant but not large. The only correlations greater than 40% are the Pearson correlation between *Contingent_Resources* and *Discoveries*, 0.43, and the Spearman correlation between *Big4* and *Equity_Compensation*, 0.41.

alternatively beginning on day $t + 7$, $t + 30$, and $t + 90$ and ending on $t + 365$, where t is the day of the reserves disclosure. Untabulated findings relating to estimating equation (1) using these alternative dependent variables reveal the same inferences as revealed by the tabulated findings.

To assess the sensitivity of our inferences to the possibility of correlated omitted variables, following Frank (2000) we simulate an omitted variable with different correlations with *Log_Future_Volatility* and *Reserves_Dispersion*. For each correlation with each variable, we estimate equation (1) and compute the *t*-statistic associated with the coefficient on *Reserves_Dispersion*. See Appendix D for details. To determine the plausibility that a correlated omitted variable would affect our inferences, we use the two control variables that exhibit the highest correlations with *Log_Future_Volatility* and *Reserves_Dispersion*. Untabulated statistics reveal that *Size* has the largest correlation with *Log_Future_Volatility*, 70%. The analysis in Appendix D reveals that an omitted variable 70% correlated with *Log_Future_Volatility* would need a correlation with *Reserves_Dispersion* larger than 40% to eliminate the significant coefficient on *Reserves_Dispersion*. However, untabulated statistics reveal that the largest correlation of any control variable with *Reserves_Dispersion* is 25%; the correlation of *Size* with *Reserves_Dispersion* is only 12%.

Untabulated statistics reveal the control variable with the largest correlation with *Reserves_Dispersion* is *Production*, –25%. The analysis in Appendix D reveals that an omitted variable 25% correlated with *Reserves_Dispersion* would need a correlation with *Log_Future_Volatility* larger than 80% to eliminate the significant coefficient on *Reserves_Dispersion*. However, untabulated statistics reveal that the largest correlation of the control variables with *Log_Future_Volatility* is 70%; the correlation between *Production* and

Log_Future_Volatility is only –11%. Although this analysis does not rule out that correlated omitted variables confound our inferences, it suggests this is not likely.

V. STOCK MARKET REACTION TO RESERVES INFORMATION

We next focus on the stock market reaction—stock price change and change in bid-ask spread—to the disclosure of reserves information. We expect the stock market reaction to the disclosed change in reserves depends on the change in the reserves dispersion if investors interpret change in the disclosed P10 and P50 as reflecting information about change in reserves dispersion, and obtain information about change in reserves from the disclosures. If investors do not interpret the disclosures this way or obtain reserves information from other sources, we will not observe findings consistent with our expectations.

Stock Price Change

Our first set of tests focuses on stock price change in the short-window centered on the disclosure of reserves information. We expect that the market's reaction to news of an increase in reserves is weaker when the news indicates that reserves dispersion is larger.[28]

Figure 2 illustrates the basis for this expectation. Firms A and B disclose reserves information with different dispersion. Firm A discloses X barrels of new reserves that have no variability, i.e., with 100% probability the firm expects the new reserves to materialize. Consequently, the dispersion associated with the revised reserves distribution is the same as that associated with the previously disclosed distribution, i.e., $Dispersion_t = Dispersion_{t-1}$ and P10 and P50 both increase by the same amount, namely X. In contrast, although firm B also discloses new reserves of X barrels, there is considerable variability relating to their extraction,

[28] This hypothesis is consistent with prior research on earnings forecasts. Clement, Frankel, and Miller (2003) documents a positive association between reduced analyst forecast dispersion—a proxy for earnings uncertainty—and the stock market response to subsequent management earnings forecasts. Zhang (2006) finds that the market under-reaction to analyst forecast revisions and momentum is greater when there is greater information uncertainty.

i.e., the firm expects the new reserves to materialize with a probability much less than 100%. Assuming the probabilities that the new and pre-existing reserves materialize are independent, the dispersion associated with firm B's revised reserves distribution is greater than the distribution associated with the previously disclosed distribution, i.e., $Dispersion_t > Dispersion_{t-1}$ and P10 increases by an amount smaller than X. Because there is no variability in firm A's new reserves, the market should react positively to the increase in its P50. However, for sufficiently large variability in firm B's new reserves, the market reaction to its disclosure will not be significant. Thus, if P50 – P10 measures the dispersion of the distribution of reserves, the change in P50 – P10, i.e., news on reserves dispersion, will moderate the stock price reaction to changes in the mean of the distribution, i.e., news on reserves levels.

To test our expectation, we partition observations into two groups, High and Low—based on the median change in *Reserves_Dispersion*, *ΔRDispersion*—and estimate equation (2) separately for each group. *ΔRDispersion* is $[(P50 - P10)_t - (P50 - P10)_{t-1}]$, scaled by $P50_{t-1}$. Using change in reserves helps ensure that the market reaction we document is attributable to new information about reserves.

$$Abnret = \delta_0 + \delta_1\, \Delta RMedian + \phi\, Controls + \varepsilon \qquad (2)$$

Abnret is the market-adjusted compounded return over the (−1, +1) day window centered on the reserves disclosure date, in %. *ΔRMedian* is change in P50, scaled by $P50_{t-1}$.[29] Because some firms disclose reserves when they announce earnings, *Controls* includes Δ*Earnings*, which is the annual percentage change in earnings before extraordinary items.[30] *Controls* comprises *Size*,

[29] P50 is the median, not the mean, of the reserves distribution. However, median reserves reasonably approximate expected reserves because, as footnote 10 explains, the distribution of O&G reserves is lognormal.
[30] To examine whether concurrent earnings disclosures confound our inferences we select a random sample of 375 firm-years and collect the earnings disclosure and reserve disclosure dates. We find that 49% (39%) of reserves disclosures are not disclosed concurrently with (at least one day before or after) the earnings disclosure. We

BM, and *Past_Return*, which prior research finds are associated with returns (Fama and French 1992; Jegadeesh and Titman 1993; Carhart 1997). Equation (2) also includes year and firm fixed effects. If P50 minus P10 reflects reserves dispersion, we expect δ_1 is positive for the Low group and not significant, or less significant, for the High group.

Change in Bid-ask Spread

Our second set of tests focuses on change in bid-ask spreads in the short window centered on the disclosure of reserves information. The theoretical market microstructure literature (e.g., Stoll 1978; Kyle 1985) explains that one component of bid-ask spread relates to costs associated with market makers holding an inventory of the firm's securities to enable them to respond to order flow. Stoll (1978) shows that an increase in firm risk can result in higher bid-ask spreads because risk-averse market makers charge more as compensation for the risk of holding shares with higher volatility, and Copeland and Galai (1983) shows that bid-ask spread is an increasing function of the asset's total risk. In addition, Kyle (1985) shows that liquidity costs, which can manifest as bid-ask spread, increase in the volatility of the security. As a result, bid-ask spread is a measure of investor uncertainty (e.g., Amihud and Mendelson 1980, 1987; Cohen, Maier, Schwartz and Whitcomb 1986; Mendelson, 1982, 1985, 1987).

Thus, if *Reserves_Dispersion* reflects information relating to the risk associated with reserves, we expect change in bid-ask spread in the short window around the disclosure to be positively associated with change in reserves dispersion. To test this, we estimate equation (3).

$$\Delta Bidask = \delta_0 + \delta_1 \, \Delta RDispersion + \phi \, Controls + \varepsilon \qquad (3)$$

$\Delta Bidask$ is average daily bid-ask spread over the (−1, +1) day window centered on the reserves disclosure minus average bid-ask spread over the previous quarter. We expect δ_1 is positive.

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estimate equation (2) using only these firm-year observations; untabulated findings reveal the same inferences as revealed by the tabulated findings.

Controls includes variables prior research finds are associated with bid-ask spreads (e.g., Glosten and Milgrom 1985; Huang and Stoll 1997), in addition to other controls specific to O&G reserves. Specifically, *Controls* includes the following variables. *Log_|ΔRMedian|*, *Log_|ΔEarnings|*, and *Log_|Abnret|* are the logarithms of the absolute value of *ΔRMedian*, *ΔEarnings*, and *Abnret*. *ΔTurnover* (*ΔMktBidask*) is the average daily share turnover (market bid-ask spread) in the (−1, +1) window minus average daily turnover (market bid-ask spread) in the (−90, −2) window relative to the reserves disclosure. *Inverse_Midpoint* is the inverse of the bid-ask spread midpoint. *Log_Bidask* is the logarithm of average *Bidask* over the 365 days prior to fiscal year end, where *Bidask* is the daily bid-ask spread, i.e., closing ask price minus closing bid price, divided by their average, in %. *Log_Volatility* (*Log_Turnover*) is the logarithm of the standard deviation of daily stock returns, in %, measured over (average daily share turnover in) the 365 days before fiscal year end. Equation (3) also includes firm and year fixed effects.

Results

Table 6 presents the results. Panel A presents descriptive statistics for the additional variables we use in estimating equations (2) and (3). Panel B presents regression summary statistics from estimating equation (2) for the Low and High *ΔRDispersion* groups. Consistent with our expectations, panel B reveals that the coefficient on *ΔRMedian* is significantly positive for the Low group (*t*-stat. = 3.00); for the High group, the coefficient is not significantly different from zero (*t*-stat. = –0.21).[31] In addition, estimating a pooled version of equation (2) permitting

[31] To determine whether the significant relation between *ΔRMedian* and *Abnret* for Low *ΔRDispersion* observations is attributable to observations with extremely low *ΔRDispersion*, we estimated equation (2) for Low *ΔRDispersion* observations, separately excluding observations in the bottom decile of *ΔRDispersion* and with *ΔRDispersion* < –0.10. Untabulated findings reveal significant positive coefficients on *ΔRMedian* for the remaining Low *ΔRDispersion* observations in both estimations. These findings are inconsistent with the tabulated findings being attributable to very low *ΔRDispersion* observations. We also estimate equation (2) including *Risk_Other_Info* and *High_ΔRDispersion* and the interactions between each of them and *ΔRMedian*; *High* denotes above the sample median. We use this interaction specification because *Risk_Other_Info* is available for less than half the sample.

all coefficients to differ for the two groups of firms reveals that the coefficient on *ΔRMedian* is significantly larger for the Low group (p-value < 0.001). Thus, the findings in panel B support the inferences we draw from table 2 that disclosed reserves dispersion provides information related to the variation in reserves.[32]

Panel C presents regression summary statistics from estimating three versions of equation (3), where the versions differ depending on which control variables we include. As expected, the coefficient on *ΔRDispersion* is positive and significant in all specifications (*t*-stats. = 2.72, 2.89, and 3.43). The magnitude of the changes in bid-ask spread associated with changes in reserves dispersion is substantial. In the column (3) version, which includes all control variables, the coefficient on *ΔRDispersion*, δ_1, is 0.12, which suggests that one standard deviation change in *ΔRDispersion* is associated with a 0.37% change in bid-ask spreads.

Taken together, the findings in table 6 indicate that the disclosure of P50 together with P10 generates significant stock price change and change in bid-ask spread that are consistent with the disclosed dispersion of O&G reserves providing information relating to firm risk.[33]

The untabulated findings reveal that, despite the smaller sample, the coefficient on *High_ΔRDispersion* × *ΔRMedian* is significantly negative (*t*-stat. = –1.68), which is consistent with the findings in table 6, and the coefficient on *High_Risk_Other_Info* × *ΔRMedian* is not significantly different from zero (*t*-stat. = 0.23).

[32] To provide corroborative evidence that the market reaction we document is related to O&G reserves, we also estimated a version of equation (2) for firms with High and Low *ΔRDispersion*, interacting *ΔRMedian*, i.e., annual change in P50, with *Pct_Discoveries*, which is the by-year rank of the percentage of *ΔRMedian* attributable to discoveries. Because investors likely have less pre-disclosure information about discoveries than other changes in P50, such as acquisitions or changes in oil and gas prices, we expect a stronger stock price reaction to the reserves disclosure when *Pct_Discoveries* is larger. Consistent with this expectation, the untabulated findings reveal a significant stock price reaction only for firms with Low *ΔRDispersion* and higher *ΔRMedian* × *Pct_Discoveries* (interaction coefficient = 7.68; *t*-stat. = 1.69).

[33] Untabulated findings reveal that our inferences are unaffected by defining *Reserves_Dispersion* and *ΔRDispersion* scaled by beginning-of-year total assets, defining *Reserves_Dispersion* in table 3 as the logarithm of (P50 – P10), and defining *ΔDispersion* in table 3 as $[(P50 - P10)_t - (P50 - P10)_{t-1}]$ scaled by $(P50 - P10)_{t-1}$. Untabulated findings also reveal that our inferences relating to bid-ask spreads are unaffected by using the Corwin and Schultz (2012) measure of bid-ask spreads; we do not have intraday trading volume and, thus, are unable to estimate directly effective spreads. The coefficient (*t*-stat.) on *Reserves_Dispersion* for the three estimations in table 6, panel C, ranges from 0.04 to 0.05 (1.93 to 2.50). Untabulated findings from estimating the table 6, panels B and C, specifications including *O&G_Controls* and *General_Controls* reveal the same inferences as revealed by the tabulated findings. These findings are consistent with Patatoukas et al. (2015), which suggest that reserves

VI. RESERVES DISPERSION AND DISCLOSURE OPPORTUNISM

A potential alternative explanation for the findings in table 6 is that higher *Reserves_Dispersion* reflects upward management of reserves (Kothari, Shu, and Wysocki 2009). That is, firms inflate probable reserves to increase P50 for opportunistic reasons, e.g., to increase investors' perception of firm value or to manage contractual commitments.[34] If so, the market reaction to higher *Reserves_Dispersion* would be attributable to a perceived increase in information risk, not to a perceived increase in risk associated with the reserves.[35]

Disclosure Incentives and Governance

To determine the extent to which opportunistic management of the disclosed reserves explains our findings, we first test whether higher *Reserves_Dispersion* is associated with incentives to disclose higher reserves and with weaker corporate governance. Specifically, we estimate equation (4).

$$Reserves\_Dispersion_{it} = \delta_0 + \delta_1\, Disclosure\ Incentives_{it} + \delta_2\, Governance\ Characteristics_{it} + \phi_1\, General\_Controls_{it} + \phi_2\, O\&G\_Controls_{it} + \varepsilon \quad (4)$$

disclosures other than reserves estimates are not relevant for equity valuation. Untabulated findings from estimating equations (1) to (3) separately for TSX and TSX-V firms reveal that the coefficients on *Reserves_Dispersion*, *Reserves_Dispersion_Q*, *ΔRMedian*, and *ΔRDispersion*, depending on the equation, are all significantly positive. The sole exception is the coefficient on *Reserves_Dispersion_Q* in equation (1) for TSX firms when the dependent variable is *Log_Future_Interest*, which is positive but not significantly different from zero. These findings indicate our inferences are not attributable to firm differences, e.g., size or volatility, associated with TSX or TSX-V listing. We also estimate equation (1) separately for firms above and below median *Size*. The untabulated findings reveal a significant positive relation between *Future_Volatility* and *Reserves_Dispersion* and *Reserves_Dispersion_Q*.

[34] For example, a typical O&G senior debt arrangement is a revolving loan facility based on and secured by reserves, and independent exploration and production firms often pledge reserves as collateral for derivatives, such as swaps.

[35] Stated differently, if disclosed reserves is $V = V^* + \varepsilon$, where V^* is reserves value and ε is measurement error, higher *Reserves_Dispersion* could reflect an increase in the dispersion of ε, rather than V^*. In addition, bid-ask spread also could increase if the quality of the disclosed information is poor, thereby potentially increasing information asymmetry (e.g., Lee, Mucklow, and Ready 1993; Krinsky and Lee 1996; Barron, Byard, and Kim 2002; Barron, Harris, and Stanford 2005). However, findings reported in the next subsection reveal that *Reserves_Dispersion* is more closely associated with economic determinants of reserves than with disclosure incentives and governance characteristics, which is not consistent with poor quality disclosure.

Table 7 presents regression summary statistics from estimating four versions of equation (4); the versions differ depending on the explanatory variables we include.

The version in column (1) of table 7 includes only *General_Controls* and *O&G_Controls* and reveals that several control variables are significant in explaining *Reserves_Dispersion*. Regarding *General_Controls*, the coefficients on *Leverage* and *ROA* are significantly negative and that on *Log_Volatility* is significantly positive (*t*-stats. = −3.43, −4.33, and 4.15). Regarding *O&G_Controls*, the coefficients on *Undeveloped Reserves*, *Production*, *Revisions*, *Percent_NatGas*, *Derivatives*, and *Investment* are significantly negative and those on *Reserves_Level* and *Dispositions* are significantly positive (*t*-stats. range from −6.47 to −1.83 and 4.29 and 2.85).[36]

The version in column (2) of table 7 also includes the *Disclosure Incentives* and *Governance Characteristics* variables. Regarding *Disclosure Incentives*, the coefficients on all four variables are positive, and two, those on *Losses* and *Equity_Compensation*, are significantly so (*t*-stats. = 3.00 and 2.22). These findings indicate that firms with stronger incentives to inflate disclosed reserves are more likely to disclose higher probable reserves, i.e., higher *Reserves_Dispersion*. Regarding *Governance Characteristics*, column (2) reveals that firms with stronger monitoring, as reflected in *Top_Evaluator*, report lower *Reserves_Dispersion* (*t*-stat. = −2.12). The coefficients on the other two *Governance Characteristics* variables are not significantly different from zero. In addition, the findings relating to *General_Controls* and *O&G_Controls* largely are unaffected by inclusion of *Disclosure Incentives* and *Governance Characteristics*. Perhaps more importantly, the adjusted R^2 in column (2) is 31.24, whereas it is

[36] The expected remaining life for oil (natural gas) reserves is 12 (9) years (see CanOils Database Manual, 2011 at www.canoils.com), which may explain the negative coefficient on *Percent_NatGas* because the shorter-lived gas reserves would be associated with less reserves risk.

27.70 in column (1). Although the 3.54 increase in adjusted R^2 is significant (p-value = 0.037), it is not large. Thus, although disclosure incentives and governance characteristics may affect disclosed reserves dispersion, more of its variation is associated with economic determinants.

Columns (3) and (4) reveal that including firm fixed effects yields fewer variables with coefficients that are significantly different from zero. Of the *Disclosure Incentives* and *Governance Characteristics* only *Losses* has a significant relation with *Reserves_Dispersion* (*t*-stat. = 2.12). This finding reveals firms with losses are more likely to report larger reserves, which is consistent with opportunistic reserves management. However, eight of the *General_Controls* and *O&G_Controls* variables are significant in explaining *Reserves_Dispersion*. Consistent with these findings, the inclusion of *Disclosure Incentives* and *Governance Characteristics* in column (4) does not significantly increase in adjusted R^2 (68.92 versus 68.77, p-value = 0.232).

Endogeneity could affect the findings in equation (4). First, reserves and accounting-based disclosure incentive variables are simultaneously determined. This is because impairment tests of recognized O&G assets and the timing of well abandonment charges employs P50, and depletion expense employs P10. Second, firms with riskier reserves could be more likely to employ a top evaluator to enhance the disclosure's credibility. However, for endogeneity to invalidate our inferences, there needs to be one or more omitted variables that are correlated with our disclosure incentives and governance characteristics variables such that the variables have weak relations with *Reserves_Dispersion* when the variables are omitted, as table 7 reports, but have strong relations when they are included. Although it is unclear whether such variables exist, to mitigate these concerns, equation (4) includes *General_Controls*, *O&G_Controls*, and firm fixed effects. Nonetheless, the findings from equation (4) should be interpreted cautiously.

Future Reserve Revisions

Based on the assumption that firms cannot sustain indefinitely upward management of reserve amounts, we next test whether subsequent technical revisions of reserves are associated with current period reserves dispersion. O&G firms are required to disclose technical revisions of prior year reserves (see Appendix A for an example).

We first consider technical revisions of P50. Table 1 reveals that mean (median) *Revisions* is –9% (−2%) of P50; untabulated statistics reveal that 60% of the revisions are negative. If the table 6 findings are attributable to estimation error in P50, we expect *Reserves_Dispersion* to be associated with future revisions. Assuming the bias is upwards, we expect a positive association between *Reserves_Dispersion* and future negative revisions. To test this association we estimate equation (5) and expect δ_1 is positive.

$$Future\_Negative\_Revisions = \delta_0 + \delta_1\, Reserves\_Dispersion + \phi_1\, General\_Controls_t + \phi_2\, O\&G\_Controls_t + \varepsilon \qquad (5)$$

Future_Negative_Revisions equals one if the firm reports negative technical revisions at least once in year $t + s$, $s = 1$ to 3, and zero otherwise, where t is the year of the disclosed reserves to which the revision relates. We construct *Future_Negative_Revisions* over three time horizons because the firm likely can sustain upwards reserves management for more than one year.[37]

Future Reserves Levels

Firms that expect lower future reserves could have greater incentives to manage current reserves upwards in an attempt to manage investors' perceptions of future profitability. We test

[37] We also estimate equation (5) using logit; the untabulated coefficients and t-statistics relating to $Reserves\_Dispersion_t$ for $s = 1$, 2, and 3 years are similar to those in table 8. Untabulated statistics also reveal that the correlation between *Future_Negative_Revisions* and *Reserves_Dispersion* is insignificant for each time horizon.

this expectation by testing whether *Reserves_Dispersion* is negatively associated with future reserves. Specifically, we estimate equation (6).

$$Log\_Future\_Reserves = \delta_0 + \delta_1\, Reserves\_Dispersion + \phi_1\, General\_Controls_t + \phi_2\, O\&G\_Controls_t + \varepsilon \qquad (6)$$

Log_Future_Reserves is the logarithm of one-year-ahead P50. We also estimate a version of equation (6) that includes the lagged dependent variable. If firms manage reserves upwards when they expect lower future reserves, we expect $\delta_1 < 0$.

Results

Table 8 presents the results from estimating equations (5) and (6), in panels A and B. Regarding future negative technical revisions, panel A reveals that the coefficient on *Reserves_Dispersion* is not significantly different from zero for any horizon, with or without inclusion of firm fixed effects (*t*-stats. range from 0.27 to 1.69 in absolute value). These findings provide no evidence of upward bias in probable reserves that subsequently is revised downwards.

Regarding future reserves, panel B reveals that the coefficient on *Reserves_Dispersion* is significantly positive in columns (1) and (2), which include *General_Controls* and *O&G_Controls*, but not the lagged dependent variable or year and firm fixed effects (*t*-stats. = 3.98 and 3.40). However, in versions that include these other variables, panel B reveals no significant relation between *Log_Future_Reserves* and *Reserves_Dispersion* (*t*-stats. range from 0.84 to 1.44). Regardless, panel B provides no evidence of a negative coefficient on *Reserves_Dispersion*, which indicates that the findings in table 6 are not attributable to firms managing reserves upwards when they expect lower reserves in the future.

VII. CONCLUDING REMARKS

This study examines information relating to the dispersion of the probability distribution of O&G reserves that is mandatorily disclosed by publicly traded Canadian O&G firms. These firms are required to disclose estimates of the 10th and 50th percentiles of the reserves distribution, which are referred to as proved reserves and proved plus probable reserves. The difference between these two amounts provides an estimate of the dispersion of the reserves distribution.

We find that the disclosed reserves dispersion information—in dollars or barrels of oil equivalents—exhibits a robust association with total future stock return volatility and its idiosyncratic and systematic components, as well as future interest expense. These findings indicate that the disclosed reserves dispersion has a significantly positive association with firm equity risk and credit risk. We also find that the stock price reaction to the reserves disclosure is weaker when the change in the disclosed reserves dispersion is larger, and that the change in the disclosed dispersion is positively associated with the change in bid-ask spread.

We conduct tests to determine whether opportunistic management of the reserve estimates explains our findings, and find little evidence that it does. We find that economic determinants of reserves are significant in explaining the disclosed reserves dispersion and that disclosure incentives and governance characteristics have limited incremental ability to explain it. In addition, we find no evidence that disclosed reserves dispersion is associated with future negative revisions in the reserves estimates, or with lower future reserves.

Taken together, our findings suggest that disclosure of the dispersion of O&G reserves provides information potentially useful to investors in assessing variation in firms' future economic performance, i.e., in assessing firm risk. Thus, our paper informs the ongoing concern

about the usefulness of disclosed reserves information. Although O&G reserves are peculiar to the industry and could be easier to value than non-financial assets in other industries, our findings suggest that disclosure of the dispersion of the probability distribution of non-financial assets can be informative about firm risk.

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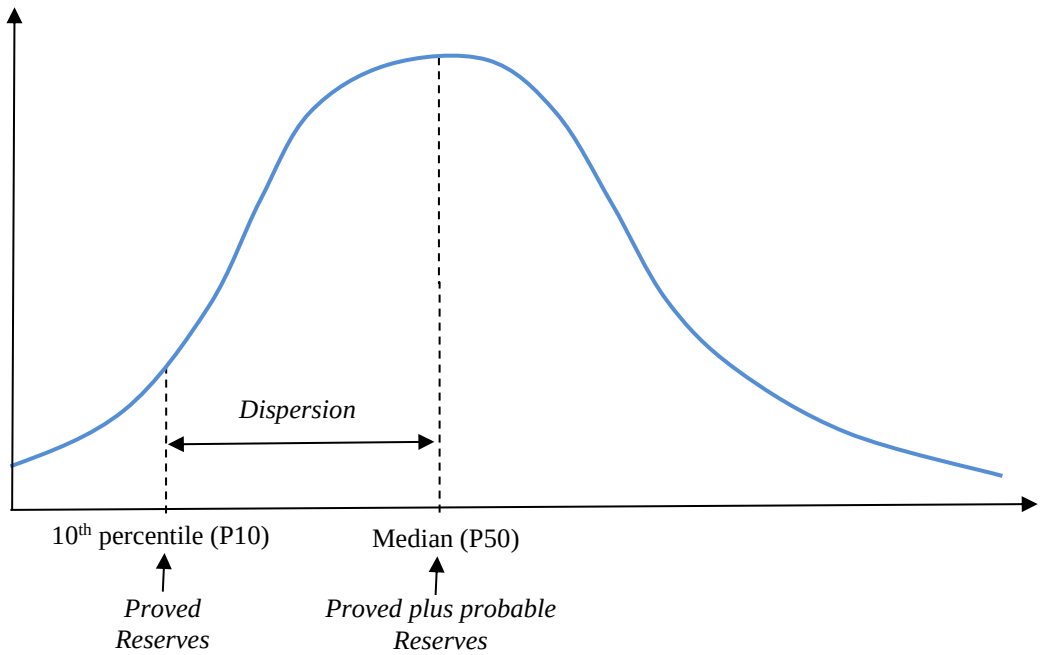
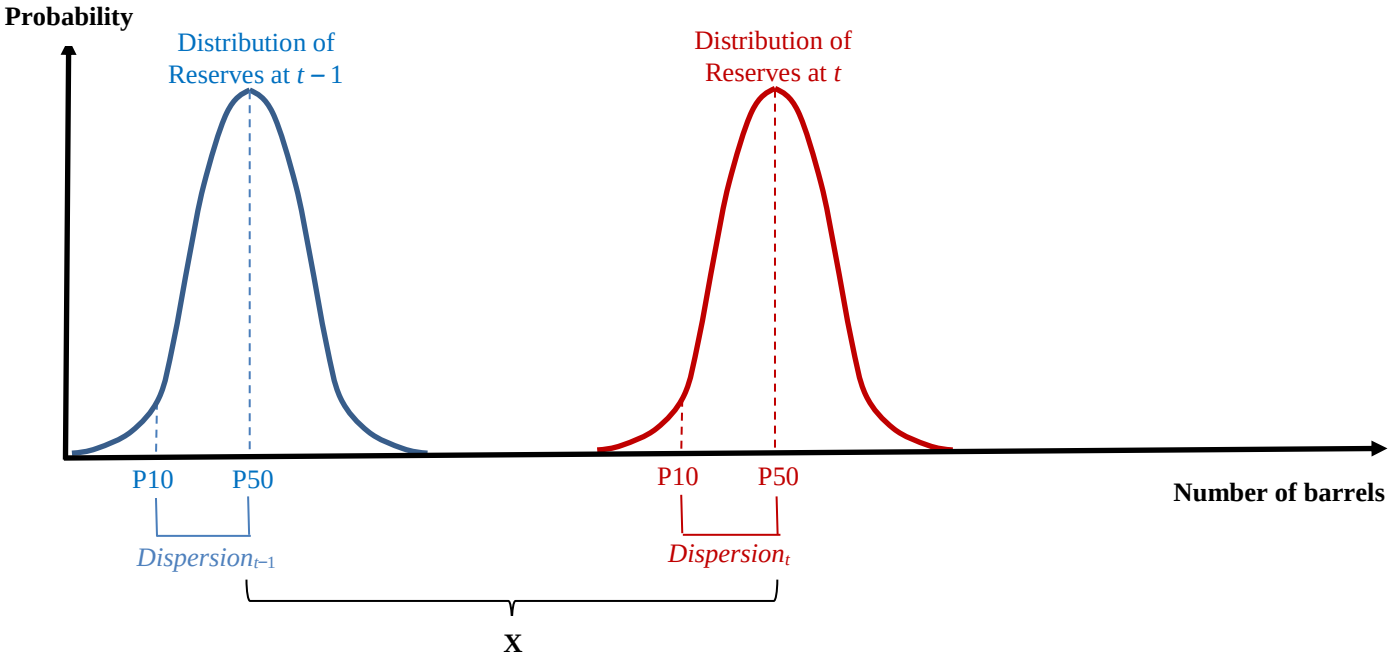
Figure 1. Regulatory Definition of Reserves Disclosures



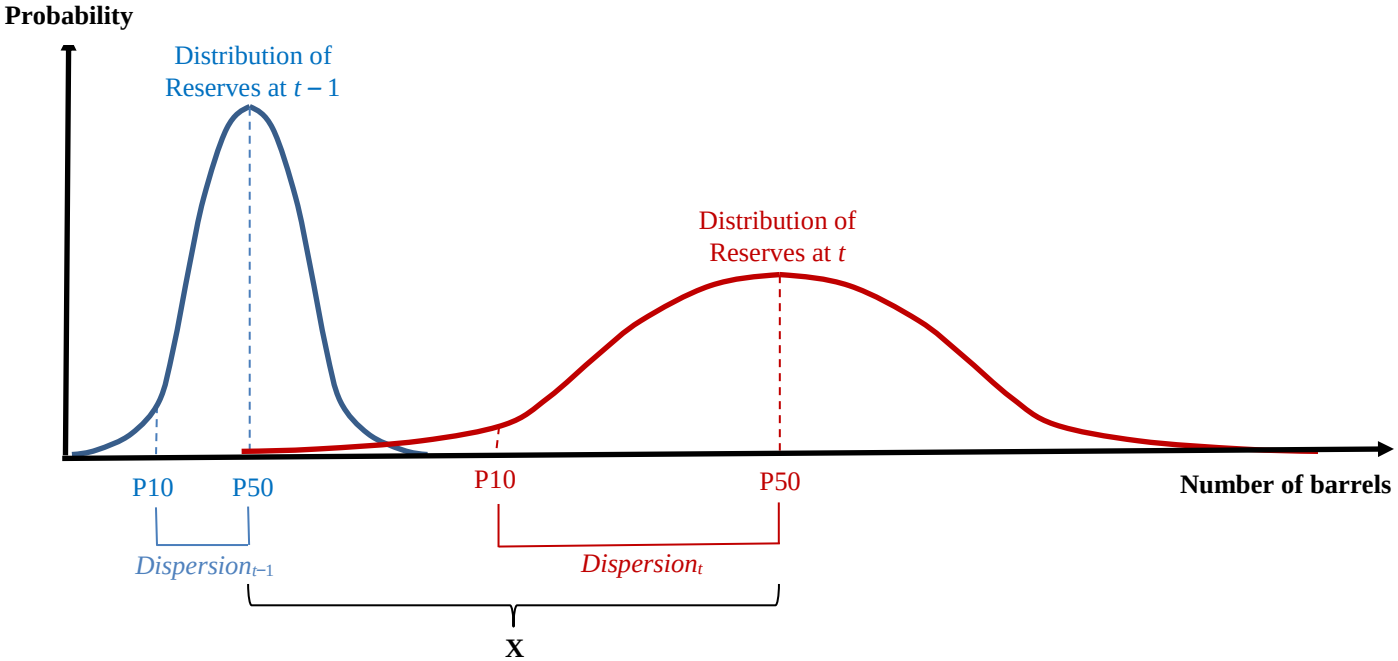
The figure illustrates the definition of proved reserves and proved plus probable reserves required to be disclosed by Canadian O&G firms in accordance with NI 51-101. The difference between the estimates reflects the distribution's dispersion. Reserves quantity, X, is the amount of petroleum that has been discovered and deemed to be economically recoverable. Proved reserves is the amount of reserves such that $P[X \geq P10] = 90\%$, and proved plus probable reserves is the amount such that $P[X \geq P50] = 50\%$, where P[.] denotes probability.

Figure 2. Variability around Reserves News and Reserves Dispersion

Firm A: Reserves increase by X with Probability = 100%



Firm B: Reserves increase by X with Probability < 100%



The figure depicts the change in the probability distribution of O&G reserves of two hypothetical firms with the same amount, X, of new reserves in year *t* but with different variability associated with the increase. For firm A, X is certain, i.e., it will materialize with a probability of 100%. For firm B, X is variable, i.e., it will materialize with a probability < 100%. Assuming the probabilities that the new and pre-existing reserves materialize are independent, the dispersion of firm A's reserves distribution does not change, i.e., $Dispersion_{t-1} = Dispersion_t$, and the dispersion of firm B's increases, i.e., $Dispersion_{t-1} < Dispersion_t$. For each firm, the probability distribution of reserves at time $t-1$ (t) is on the left (right). P10 and P50 refer to the 10th and 50th percentiles of the reserves distribution.

Appendix A. Examples of Reserves Disclosures

A.1. Crew Energy Inc. Disclosure of reserves (as of December 31, 2006)

	NET PRESENT VALUES OF FUTURE NET REVENUE									
	BEFORE INCOME TAXES DISCOUNTED AT (%/year)					AFTER INCOME TAXES DISCOUNTED AT (%/year)				
RESERVES CATEGORY	0% (M$)	5% (M$)	10% (M$)	15% (M$)	20% (M$)	0% (M$)	5% (M$)	10% (M$)	15% (M$)	20% (M$)
PROVED										
Producing	216,920	180,172	155,620	137,833	124,328	208,855	174,659	151,405	134,524	121,673
Developed Non-Producing	85,429	70,709	60,812	53,694	48,314	58,523	48,817	42,427	37,888	34,477
Undeveloped	10,969	5,739	2,602	624	-675	7,421	3,288	797	-775	-1,803
TOTAL PROVED	312,688	256,619	219,034	192,152	171,966	274,799	226,765	194,630	171,638	154,348
TOTAL PROBABLE	156,470	98,167	67,416	49,082	37,178	107,070	65,834	44,231	31,387	23,069
TOTAL PROVED PLUS PROBABLE	469,158	354,785	286,451	241,233	209,145	381,868	292,599	238,860	203,024	177,416

A.2. Crew Energy Inc. Year-to-year reconciliation of reserves (as of December 31, 2006)

	Proved Producing	Total Proved	Total Proved plus Probable
	(Mboe)	(Mboe)	(Mboe)
Balance December 31, 2005	7,529	9,769	15,144
Technical revisions	-363	-1,136	-2,795
Exploration discoveries	128	1,096	1,376
Drilling extensions	1,356	3,085	5,346
Infill drilling	104	104	132
Improved recoveries	74	64	153
Acquisitions	1,866	2,447	3,839
Production	-2,079	-2,079	-2,079
Balance December 31, 2006	8,615	13,350	21,116

A barrel of oil equivalent (BOE) is a measure equivalent to 6,000 ft.^{3} of natural gas. O&G reserves quantity, X, is the amount of petroleum that has been discovered and deemed to be economically recoverable. Proved reserves is the amount of reserves such that $P[X \geq P10] = 90\%$, and proved plus probable reserves is the amount of reserves such that $P[X \geq P50] = 50\%$, where P[.] denotes probability. The conversion from physical units into dollars is based on a discounted cash flow model using assumptions about the future production schedule of the reserves volumes, O&G prices, and extraction costs, based on alternative assumptions regarding taxes and discount rates. Technical revisions are changes in reserves estimates, by type of O&G product and measured in physical units, in properties owned by the firm at the start of the reconciliation period as the result of new technical information, including from production. Technical revisions do not relate to new investment and operational decisions or economic factors. Source: Crew Energy Inc. Form 51-101F1 corresponding to fiscal year 2006 and filed on 3/29/2007.

Appendix B. Reserves Dispersion Assuming Lognormality

This appendix derives the expression for the variance, σ, of the probability distribution of the logarithm of a random variable X, i.e., log(X), as a function of the lowest decile, P10, and the median, P50, of X, assuming that the probability distribution of log(X) is normal.

The αth percentile of the distribution can be expressed as:

$$P(X > X_\alpha) = \frac{\alpha}{100} \tag{B1}$$

The logarithmic transformation of X is:

$$P(\log(X) > \log(X_\alpha)) = \frac{\alpha}{100} \tag{B2}$$

Standardizing X to create Z, the αth percentile of the distribution of Z can be expressed as:

$$P\left(Z > \frac{\log(X_\alpha) - \mu}{\sigma}\right) = \frac{\alpha}{100} \tag{B3}$$

where μ is the mean of log(X). Because log(X) is normally distributed, the mean of log(X) equals the median of log(X). That is, $\mu = \log(X_{50})$. Thus, (B3) can be expressed as:

$$\log\left(\frac{X_\alpha}{X_{50}}\right) = \sigma Z_\alpha \tag{B4}$$

For $\alpha = 0.10$, i.e., the lowest decile P10, $Z_\alpha = -1.282$ and thus:

$$\sigma = \frac{\ln\left(\frac{P10}{P50}\right)}{-1.282} \tag{B5}$$

P10 can be expressed as a function of P50 and probable reserves, i.e., our measure of reserves dispersion:

$$P10 = P50 - Probable \tag{B6}$$

Thus:

$$\sigma = \frac{\ln(1 - \frac{Probable}{P50})}{-1.282} \tag{B7}$$

That is, σ can be expressed as a monotonic transformation of our reserves dispersion measure, i.e., $\frac{P50 - P10}{P50}$.

The untabulated Pearson correlation between *Reserves_Dispersion* and σ computed as in equation (B7) is 0.94 (0.87) basing σ on P50 and P10 expressed in $ (BOE). In addition, untabulated findings based on using σ in place of *Reserves_Dispersion* yields the same inferences as those we tabulate, regardless of whether we measure reserves in $ or BOEs.[38]

[38] Untabulated *t*-statistics associated with the coefficient on σ, as defined in equation (B7), in the five specifications presented in table 2 range from 2.67 to 5.30. For consistency, in these estimations, we replace *Median_Reserves* with the mean of the lognormal reserves distribution, i.e., $P50 * e^{0.5\sigma^2}$.

Appendix C. Variable Definitions

Reserves Dispersion and Firm Risk

Reserves_Dispersion (Reserves_Dispersion_Q)	Dispersion of the distribution of the dollar amount (quantity) of O&G reserves, scaled by the dollar amount (quantity) size of the reserves. It equals (P50 − P10) / P50, where P50 and P10 are the median and bottom decile of the reported distribution of the estimated dollar amount (quantity) of the reserves. Quantity is in BOEs
Log_Future_Volatility	Logarithm of the standard deviation of daily stock returns, in %, in the 365 days following the annual reserves disclosure; the lagged version is stock returns in the 365 days before the disclosure
Future_Beta	Average daily CAPM beta, i.e., the slope coefficient from a regression of daily stock returns in excess of the risk-free rate on daily market returns in excess of the risk-free rate. The estimation period is the 365 days subsequent to the annual reserves disclosure
Log_Future_Idiosyn	Logarithm of the standard deviation of the residuals from the market model used to calculate *Future_Beta*, in %
Future_Interest	Net interest expenses scaled by net debt, i.e., debt minus cash. Net debt is the average of net debt at the beginning and end of the year

General_Controls

Size	Logarithm of equity market value at fiscal year end
BM	Ratio of book value of equity to market value of equity at fiscal year-end
Leverage	Total liabilities divided by total assets at fiscal year-end
ROA	Return on assets, i.e., earnings before extraordinary items, scaled by total assets at fiscal year-end
Past_Return	Stock return compounded daily over the 365 days prior to fiscal year end
Log_Bidask	Logarithm of average *Bidask* over the 365 days prior to fiscal year end. *Bidask* is daily bid-ask spread, i.e., closing ask price minus closing bid price, divided by their average, in %

O&G_Controls

Log_Reserves_Median	Logarithm of O&G reserves measured at the median, i.e., logarithm of P50
Undeveloped_Reserves	Undeveloped reserves in BOEs, scaled by P50 in BOEs. Undeveloped reserves are reserves on which wells have not been drilled or completed to a point that would permit production of commercial quantities of O&G
Contingent_Reserves	Discovered petroleum in place that is not commercially viable under current economic conditions in dollars, scaled by P50
Discoveries	Exploration discoveries and extensions, plus reserves discovered in prior years that become economically viable in the current year in BOEs, scaled by P50 in BOEs

Acquisitions	Acquisitions of reserves in BOEs, scaled by P50 in BOEs
Dispositions	Dispositions of reserves in BOEs, scaled by P50 in BOEs
Production	Production volume in BOEs, scaled by P50 in BOEs
Recoveries	Improved recoveries of reserves and infill drillings in BOEs, scaled by P50 in BOEs
Revisions	Revisions of previously disclosed reserves om BOEs, scaled by P50 in BOEs
Percent_NatGas	Fraction of total reserves that are natural gas, based on proved reserves in BOEs
Derivatives	Indicator variable that equals one if the firm has any nonzero asset or liability related to gains or losses on derivative instruments classified as financial instruments, and zero otherwise
Investment	Capital expenditures, scaled by total assets

Disclosure Incentives* and *Governance Characteristics

Negative_FCF	Indicator variable that equals one if the free cash flow, i.e., the sum of total annual cash from operating activities and total annual cash from investing activities, is negative, and zero otherwise
Losses	Indicator variable that equals one if annual earnings are negative, and zero otherwise
Equity_Compensation	Logarithm of annual stock-based compensation expense
Impairment	O&G assets write-downs, scaled by carrying amount of O&G reserves
Reserves_Committee	Indicator variable that equals one if the firm has a reserves committee, and zero otherwise
Big4	Indicator variable that equals one if the firm is audited by a Big 4 accounting firm, i.e., Deloitte, EY, KPMG, and PwC, and zero otherwise
Top_Evaluator	*Indicator* variable that equals one if the evaluator of reserves is among the top evaluators in terms of market share, and zero otherwise

Other Measures of Firm Risk

Distance to Default

Distance to default computed as in Bharath and Shumway (2008). It is $\mathrm{N}(-DD)$, where N is the standard normal distribution and *DD* is the distance to default, computed as

$$DD = \frac{ln\left(\frac{E+D}{D}\right) + (r_{i,t-1} - 0.5{\sigma_A}^2)T}{\sigma_A\sqrt{T}}$$

where E is market value of equity, D is book value of debt, σ_A is unlevered volatility, $r_{i,t-1}$ is stock return over the previous year, and T is the one-year forecasting horizon

Risk_Other_Info

Measure of exploration risk based on Sunder (1976) and Rajgopal and Shevlin (2002). It is the variance of expected future operating cash flows from exploration activity in year t, $x^2LN\theta(1-\theta)$, scaled by the mean, $xLN\theta - Nc$. L is the weighted

	average estimated remaining life of the firm's wells; N is the number of net exploratory wells drilled in year t; θ is the probability an exploratory well results in the discovery of exploitable reserves; c is the exploration cost per well; and x is the present value of cash flows per successful well

Stock Market Reaction to Disclosures of Reserves Dispersion

ΔRDispersion	Annual change in disclosed dispersion of the distribution of reserves, scaled by P50 at the beginning of the year
Abnret	Market-adjusted average daily return compounded over the (−1, +1) day window around the annual disclosure of O&G reserves, i.e., AIF Annual Report filing, in %. The market return is the average TSX Composite Index
ΔRMedian	Annual change in P50, scaled by P50 at the beginning of the year
ΔEarnings	Annual change in earnings before extraordinary items, scaled by total assets at the beginning of the year
ΔBidask	Average *Bidask* over the (−1, +1) day window around the annual reserves disclosure, i.e., AIF Annual Report filing, minus average *Bidask* over the (−90, −2) day window
Log_|ΔRMedian|	Logarithm of the absolute value of *ΔRMedian*
Log_|ΔEarnings|	Logarithm of the absolute value of *ΔEarnings*
Log_|Abnret|	Logarithm of the absolute value of *Abnret*
ΔTurnover	Average *Turnover* over the (−1, +1) day window around the annual disclosure of O&G reserves, i.e., AIF Annual Report filing, minus average *Turnover* over the (−90, −2) day window. *Turnover* is the total number of shares traded daily divided by average number of shares outstanding
ΔMktBidask	Average *MktBidask* over the (−1, +1) day window around the annual disclosure of O&G reserves, i.e., AIF Annual Report filing, minus average *MktBidask* over the (−90, −2) day window around the same date. *MktBidask* is market bid-ask spread, i.e., average *Bidask* of firms listed on the TSX and TSX-V exchanges
Inverse_Midpoint	Inverse of the midpoint of bid-ask spread
Log_Volatility	Logarithm of the standard deviation of daily stock returns, in %, measured over the 365 days before fiscal year end
Log_Turnover	Logarithm of average *Turnover* over the 365 days prior to the fiscal year end

All amounts denominated in foreign currency are converted to Canadian dollars using the spot rate at the end of the fiscal year for statement of financial position items, and the annual average exchange rate for income and cash flow statement items. Unless stated otherwise, dollar amounts are in thousands of Canadian dollars.

Appendix D. Sensitivity Analysis based on Simulation of an Omitted Variable

Following Frank (2000), we simulate an omitted variable, *Z*, with different degrees of correlation with *Log_Future_Volatility* and *Reserves_Dispersion*. For each degree of correlation with each variable, we re-estimate equation (1) including the simulated variable and compute the *t*-statistic for the coefficient on *Reserves_Dispersion*. That is, we estimate

$$\begin{aligned} Log\_Future\_Volatility = {} & \delta_0 + \delta_1\, Reserves\_Dispersion_t + \phi_1\, Z + \phi_2\, General\_Controls_t \\ & + \phi_3\, O\&G\_Controls_t + \phi_4\, Lagged\_Dep\_Variable \\ & + Year\ fixed\ effects + \varepsilon \end{aligned} \qquad (D1)$$

We generate *Z* as follows. We first generate Z_1 (Z_2) by randomizing the order of a percentage of *Log_Future_Volatility* (*Reserves_Dispersion*) observations, where the percentage ranges from 0% to 100% in increments of 1%. Then, we construct $Z = w_1 \times Z_1 + (1 - w_1) \times Z_2$, where for each Z_1 and Z_2 pair, we generate values of w_1 ranging from 0 to 1 in increments of 0.1. This procedure generates a total of 1,111 values of *Z*.

The table below presents the average *t*-statistics for the coefficient δ_1 for each of the ranges of correlation with *Log_Future_Volatility* and *Reserves_Dispersion*, where *t*-statistics are computed based on standard errors clustered by firm and year. The shaded cells indicate correlation pairs that would not affect our inferences. For example, including in equation (1) a variable that is 70% correlated with *Log_Future_Volatility* and 25% correlated with *Reserves_Dispersion* would result in a *t*-statistic of 2.79 on *Reserves_Dispersion*, which does not alter our inference.

		Correlation of *Z* with *Reserves_Dispersion*				
		0 to 20%	20 to 40%	40 to 60%	60 to 80%	80 to 100%
Correlation of *Z* with *Log_Future_Volatility*	0 to 20%	3.75	3.64	3.52	3.43	3.24
	20 to 40%	3.77	3.68	2.91	2.26	1.48
	40 to 60%	3.98	3.13	1.39	–0.59	–3.95
	60 to 80%	4.14	2.79	–0.40	–5.67	–6.29
	80 to 100%	4.13	1.57	–10.60	–11.47	-

Table 1
Descriptive Statistics

Variables	Mean	Median	Std
Experimental variables			
Reserves_Dispersion	0.36	0.32	0.18
Reserves_Dispersion_Q	0.41	0.37	0.17
Dependent variables			
Log_Future_Volatility	1.58	1.59	0.64
Future_Beta	1.15	1.19	0.81
Log_Future_Idiosyn	1.51	1.53	0.69
Future_Interest	0.06	0.05	0.09
General_Controls			
Size	4.26	4.22	2.30
BM	1.23	0.68	1.99
Leverage	0.25	0.23	0.21
ROA	–0.12	–0.03	0.40
Past_Return	0.30	–0.07	1.82
Log_Bidask	1.17	1.29	1.49
O&G_Controls			
Log_Reserves_Median	1.51	1.25	1.24
Undeveloped_Reserves	0.16	0.12	0.17
Contingent_Reserves	0.71	0.05	3.51
Discoveries	0.21	0.13	0.25
Acquisitions	0.10	0.00	0.20
Dispositions	0.06	0.00	0.32
Production	0.10	0.09	0.10
Recoveries	0.01	0.00	0.05
Revisions	–0.09	–0.02	0.39
Percent_NatGas	0.56	0.63	0.37
Derivatives	0.40	0.00	0.49
Investment	0.30	0.26	0.28
Disclosure Incentives			
Negative_FCF	0.78	1.00	0.41
Losses	0.63	1.00	0.48
Equity_Compensation	6.08	6.59	2.69
Impairment	0.06	0.00	0.23
Governance Characteristics			
Reserves_Committee	0.77	1.00	0.42
Big4	0.73	1.00	0.44
Top_Evaluator	0.80	1.00	0.40
Other Variables			
Risk_Other_Info	2.00	1.96	1.85
Distance to Default	0.09	0.00	0.27

This table presents distributional statistics for the variables we use in our tests based on a sample of 1,156 Canadian O&G firm-years from 2004 to 2011. See Appendix C for variable definitions.

Table 2
Reserves Dispersion and Equity Risk

	Dependent Variable: *Log_Future_Volatility*				
Explanatory Variables	(1)	(2)	(3)	(4)	(5)
Reserves_Dispersion	0.49***	0.57***	0.44***	0.38***	0.17***
	(5.59)	(5.31)	(3.34)	(3.45)	(2.68)
General_Controls					
Size	–0.12***	–0.07**	–0.06*	–0.04*	–0.04
	(–2.64)	(–2.37)	(–1.70)	(–1.82)	(–1.09)
BM	0.02**	0.04***	0.02*	0.03***	0.01
	(2.40)	(3.02)	(1.95)	(2.75)	(1.55)
Leverage	0.02	0.28***	0.27**	0.22***	0.19*
	(0.27)	(2.47)	(2.33)	(2.60)	(1.71)
ROA	–0.24***	–0.14	–0.07	–0.08**	–0.04
	(–2.74)	(–1.53)	(–1.03)	(–2.19)	(–1.05)
Past_Return	–0.02	–0.02	–0.03	–0.01	–0.01
	(–1.27)	(–1.21)	(–1.63)	(–0.76)	(–0.95)
Log_Bidask	0.08	0.06	–0.01	0.03	0.07**
	(1.24)	(1.01)	(–0.22)	(1.43)	(2.13)
O&G_Controls					
Log_Reserves_Median		–0.06***	–0.06***	–0.04***	–0.04
		(–3.05)	(–3.03)	(–4.62)	(–1.52)
Undeveloped_Reserves		0.24***	0.19***	0.16***	–0.32***
		(3.58)	(3.99)	(3.11)	(–3.62)
Contingent_Reserves		0.00	0.00	0.00	0.00
		(1.37)	(1.31)	(1.32)	(0.19)
Discoveries		0.01	–0.01	–0.04	0.01
		(0.20)	(–0.18)	(–0.78)	(0.22)
Acquisitions		–0.03	–0.04	–0.08	0.00
		(–0.32)	(–0.46)	(–1.21)	(0.04)
Dispositions		0.11***	0.12***	0.07***	0.04
		(4.18)	(5.68)	(4.27)	(1.50)
Production		0.02	0.00	–0.05	–0.12
		(0.15)	(–0.03)	(–0.40)	(–0.74)
Recoveries		–0.51	–0.47	–0.75	–0.87
		(–1.28)	(–1.19)	(–2.08)	(–3.10)
Revisions		0.01	0.01	–0.02	0.00
		(0.19)	(0.29)	(–0.83)	(–0.09)
Percent_NatGas		0.00	0.02	0.02	0.02
		(0.01)	(0.76)	(0.59)	(0.44)
Derivatives		–0.07*	–0.06**	–0.03*	0.00
		(–1.90)	(–2.04)	(–1.81)	(–0.07)
Investment		0.10	0.12	0.06*	0.02
		(0.97)	(1.16)	(1.66)	(0.52)
Lag_Dep_Variable			0.29***	0.34***	–0.06
			(2.75)	(3.05)	(–0.75)
Year Fixed Effects				YES	YES
Firm Fixed Effects					YES
Adj. R^2	56.43%	58.70%	61.32%	75.25%	85.12%

This table presents regression summary statistics from estimating the relation between the disclosed dispersion of O&G reserves, *Reserves_Dispersion*, and firm risk, as reflected in future equity volatility, *Log_Future_Volatility*. Estimations are based on a sample of 1,156 Canadian O&G firm-years from 2004 to 2011. *Lag_Dep_Variable* is the lagged dependent variable; see Appendix C for other variable definitions. *t*-statistics (in parentheses) are based on standard errors clustered by firm and year. *, **, and *** denote significance at the 10%, 5%, and 1% levels.

Table 3
Systematic, Idiosyncratic, and Credit Risks

Panel A. Systematic Risk

	Dependent Variable: *Future_Beta*				
Explanatory Variables	(1)	(2)	(3)	(4)	(5)
Reserves_Dispersion	0.48***	0.60***	0.44***	0.43***	0.33**
	(3.60)	(4.91)	(3.97)	(4.08)	(2.33)
General_Controls	YES	YES	YES	YES	YES
O&G_Controls		YES	YES	YES	YES
Lag_Dep_Variable			YES	YES	YES
Year Fixed Effects				YES	YES
Firm Fixed Effects					YES
Adj. R^2	28.30%	30.98%	33.80%	36.20%	57.23%

Panel B. Idiosyncratic Volatility

	Dependent Variable: *Log_Future_Idiosyn*				
Explanatory Variables	(1)	(2)	(3)	(4)	(5)
Reserves_Dispersion	0.52***	0.60***	0.45***	0.39***	0.15**
	(5.59)	(5.48)	(3.21)	(3.24)	(2.28)
General_Controls	YES	YES	YES	YES	YES
O&G_Controls		YES	YES	YES	YES
Lag_Dep_Variable			YES	YES	YES
Year Fixed Effects				YES	YES
Firm Fixed Effects					YES
Adj. R^2	62.58%	64.74%	67.68%	77.93%	86.71%

Panel C. Credit Risk

	Dependent Variable: *Future_Interest*				
Explanatory Variables	(1)	(2)	(3)	(4)	(5)
Reserves_Dispersion	0.05***	0.05***	0.05***	0.06***	0.07***
	(2.79)	(3.95)	(3.37)	(3.69)	(4.36)
General_Controls	YES	YES	YES	YES	YES
O&G_Controls		YES	YES	YES	YES
Lag_Dep_Variable			YES	YES	YES
Year Fixed Effects				YES	YES
Firm Fixed Effects					YES
Adj. R^2	7.07%	10.18%	15.57%	18.59%	46.91%

This table presents regression summary statistics from estimating the relation between the disclosed dispersion of O&G reserves, *Reserves_Dispersion*, and systematic risk, *Future_Beta*, idiosyncratic risk, *Log_Future_Idiosyn*, and credit risk, *Future_Interest*. Estimations are based on a sample of 1,156 Canadian O&G firm-years from 2004 to 2011. *Lag_Dep_Variable* is the lagged dependent variable and *General_Controls* and *O&G_Controls* are as in table 2; see Appendix C for other variable definitions. *t*-statistics (in parentheses) are based on standard errors clustered by firm and year. *, **, and *** denote significance at the 10%, 5%, and 1% levels.

Table 4
Reserves Dispersion based on Reserves Volume

Panel A. Equity Risk

	Dependent Variable: *Log_Future_Volatility*				
Explanatory Variables	(1)	(2)	(3)	(4)	(5)
Reserves_Dispersion_Q	0.58***	0.73***	0.59***	0.51***	0.38***
	(6.24)	(5.77)	(3.83)	(4.62)	(4.79)
General_Controls	YES	YES	YES	YES	YES
O&G_Controls		YES	YES	YES	YES
Lag_Dep_Variable			YES	YES	YES
Year Fixed Effects				YES	YES
Firm Fixed Effects					YES
Adj. R^2	56.88%	59.51%	61.91%	75.69%	85.31%

Panel B. Systematic, Idiosyncratic, and Credit Risks

	Dependent Variable:		
Explanatory Variables	*Future_ Beta* (1)	*Log_Future_ Idiosyn* (2)	*Log_Future_ Interest* (3)
Reserves_Dispersion_Q	0.62***	0.35***	0.09***
	(4.48)	(4.45)	(3.58)
General_Controls	YES	YES	YES
O&G_Controls	YES	YES	YES
Lag_Dep_Variable	YES	YES	YES
Year Fixed Effects	YES	YES	YES
Firm Fixed Effects	YES	YES	YES
Adj. R^2	57.52%	86.85%	47.08%

This table presents regression summary statistics from estimating the relation between the disclosed dispersion of O&G reserves expressed in barrel of oil equivalents (BOEs), *Reserves_Dispersion_Q*, and equity risk, *Log_Future_Volatility*, systematic risk, *Future_Beta*, idiosyncratic risk, *Log_Future_Idiosyn*, and credit risk, *Future_Interest*. Estimations are based on a sample of 1,156 Canadian O&G firm-years from 2004 to 2011. *Lag_Dep_Variable* is the lagged dependent variable and *General_Controls* and *O&G_Controls* are as in table 2; see Appendix C for other variable definitions. *t*-statistics (in parentheses) are based on standard errors clustered by firm and year. *, **, and *** denote significance at the 10%, 5%, and 1% levels.

Table 5
Additional Control Variables

	Dependent Variable: *Log_Future_Volatility*					
	Estimation of risk based on other disclosures		Financial distress		Managerial Opportunism	
Explanatory Variables	(1)	(2)	(3)	(4)	(5)	(6)
Reserves_Dispersion	1.08***	0.61***	1.19***	0.49***	0.54***	0.46***
	(3.45)	(4.46)	(5.42)	(2.80)	(5.71)	(4.51)
Risk_Other_Info	0.07***	0.00				
	(3.85)	(0.16)				
Distance to Default			0.66***	0.09*		
			(8.60)	(1.82)		
Disclosure Incentives						
Negative_FCF					0.15***	0.04
					(2.97)	(1.27)
Losses					0.39***	0.14***
					(5.19)	(4.41)
Equity_Compensation					–0.06***	0.01
					(–6.24)	(0.66)
Impairment					0.23***	–0.04
					(3.52)	(–0.27)
Governance Characteristics						
Reserves_Committee					–0.17***	–0.04
					(–4.15)	(–1.31)
Big4					–0.21***	–0.04
					(–3.61)	(–1.15)
Top_Evaluator					0.03	0.04
					(0.58)	(0.79)
General_Controls		YES		YES		YES
O&G_Controls		YES		YES		YES
Year Fixed Effects		YES		YES		YES
Adj. R^2	11.63%	78.53%	17.17%	75.98%	38.83%	73.58%

This table presents results of estimating the association between disclosures of reserves dispersion and equity risk including additional control variables. Results are based on a sample of Canadian O&G firm-years from 2004 to 2011. Columns (1) and (2) include 454 observations with non-missing values of *Risk_Other_Info*, and columns (3) and (4) include 771 observations with non-missing values of *Distance to Default*. Columns (5) and (6) include 1,156 observations. *General_Controls* and *O&G_Controls* are as in table 2. See Appendix C for variable definitions. *Lag_Dep_Variable* is the lagged dependent variable. *t*-statistics (in parentheses) are based on standard errors clustered by firm and year. *, **, and *** denote significance at the 10%, 5%, and 1% levels.

Table 6
Stock Market Reaction to Disclosures of O&G Reserves

Panel A. Distributional Statistics

Variables	Mean	Median	Std
ΔRDispersion	0.06	0.43	3.05
Stock price change			
Abnret	0.00	1.17	15.41
ΔRMedian	0.19	0.88	3.91
ΔEarnings	0.00	0.01	0.41
Change in bid-ask spread			
ΔBidask	−0.10	−0.21	8.07
Log_|ΔRMedian|	−1.09	−1.13	1.50
Log_|ΔEarnings|	−2.43	−2.57	1.53
Log_|Abnret|	5.69	4.50	3.10
ΔTurnover	−0.02	0.04	0.36
ΔMktBidask	−0.19	−0.31	1.38

Panel B. Stock Price Change

		Dependent Variable: *Abnret*	
		ΔRDispersion	
Explanatory Variables		Low (1)	High (2)
ΔRMedian	β	5.14***	–0.02
		(3.00)	(–0.21)
ΔEarnings		0.57	2.11
		(0.56)	(1.39)
Size		–1.36*	0.02
		(–1.80)	(0.03)
BM		0.14	–0.18
		(0.30)	(–0.69)
Past_Return		–0.80	0.01
		(–1.26)	(0.05)
Year Fixed Effects		YES	YES
Firm Fixed Effects		YES	YES
Adj. R^2		5.02%	0.24%
Test of equality of β, Low – High: *p*-value < 0.001			

Table 6 (continued)
Stock Market Reaction to Disclosures of O&G Reserves

Panel C. Change in Bid-ask Spread

	Dependent Variable: *ΔBidask*		
Explanatory Variables	(1)	(2)	(3)
ΔRDispersion	0.07***	0.08***	0.12***
	(2.72)	(2.89)	(3.43)
Controls in changes			
Log_|ΔRMedian|	–0.04	–0.11	–0.12
	(–0.48)	(–1.28)	(–0.95)
Log_|ΔEarnings|	0.03	0.01	–0.05
	(0.41)	(0.15)	(–0.37)
Log_|Abnret|	0.02	0.00	0.06
	(0.34)	(–0.06)	(0.76)
ΔTurnover	–0.57***	–0.53**	–0.66**
	(–2.65)	(–2.26)	(–2.37)
ΔMktBidask	0.73***	0.58*	0.63**
	(2.75)	(1.96)	(2.31)
Controls in levels			
Inverse_Midpoint		0.02	0.01
		(0.57)	(0.20)
Log_Bidask		–0.25	–0.06
		(–0.84)	(–0.16)
Size		0.23	0.55**
		(1.43)	(2.27)
Log_Volatility		1.17***	1.34***
		(3.12)	(2.99)
Log_Turnover		–0.04	–0.16
		(–0.29)	(–0.86)
Year Fixed Effects			YES
Firm Fixed Effects			YES
Adj. R^2	1.46%	3.42%	6.67%

This table presents evidence on the stock market reaction to disclosures of O&G reserves. Results are based on a sample of 1,156 Canadian O&G firm-years from 2004 to 2011. Panel A reports descriptive statistics for the variables we use in our tests. Panel B reports regression summary statistics from estimating the stock price reaction to the disclosure of dispersion in O&G reserves. High (Low) denotes above (below) median change in the disclosed dispersion of reserves, *ΔRDispersion*. Panel C reports regression summary statistics from estimating change in bid-ask spreads on change in the dispersion of reserves. See Appendix C for variable definitions. *t*-statistics (in parentheses) are based on standard errors clustered by disclosure date. *, **, and *** denote significance at the 10%, 5%, and 1% levels.

Table 7
Determinants of Reserves Dispersion

	Dependent Variable: *Reserves_Dispersion*			
	(1)	(2)	(3)	(4)
Disclosure Incentives				
Negative_FCF		0.02		0.00
		(1.61)		(–0.03)
Losses		0.05***		0.02**
		(3.00)		(2.12)
Equity_Compensation		0.01**		0.00
		(2.22)		(–1.27)
Impairment		0.03		0.02
		(1.24)		(0.56)
Governance Characteristics				
Reserves_Committee		0.02		–0.01
		(1.11)		(–1.03)
Big4		0.01		0.02
		(0.53)		(1.14)
Top_Evaluator		–0.06***		–0.02
		(–2.12)		(–0.70)
General Controls				
Size	–0.01	–0.01	0.00	0.00
	(–0.82)	(–1.18)	(0.20)	(0.52)
BM	0.00	–0.01	0.00	0.00
	(–0.61)	(–1.15)	(–0.99)	(–1.07)
Leverage	–0.16	–0.15***	–0.06	–0.05
	(–3.43)	(–3.22)	(–1.54)	(–1.40)
ROA	–0.07	–0.05***	–0.04	–0.03
	(–4.33)	(–2.81)	(–2.49)	(–1.35)
Past_Return	0.00	0.00	0.00	0.00
	(–0.42)	(–0.32)	(–0.67)	(–0.65)
Log_Bidask	0.01	0.02	0.02	0.02
	(0.61)	(1.41)	(1.91)	(1.76)
Log_Volatility	0.10	0.09***	0.03	0.02**
	(4.15)	(3.83)	(2.50)	(2.18)
O&G Controls				
Reserves_Level	0.04***	0.04***	0.02*	0.02*
	(4.29)	(5.22)	(1.85)	(1.78)
Undeveloped_Reserves	–0.12**	–0.17***	–0.16**	–0.17***
	(–2.18)	(–3.47)	(–2.35)	(–2.65)
Contingent_Reserves	0.00	0.00	0.00	0.00
	(0.49)	(0.29)	(–1.07)	(–1.01)
Discoveries	0.02	0.02	0.06**	0.06**
	(0.73)	(0.75)	(2.04)	(2.16)
Acquisitions	0.00	–0.01	0.01	0.01
	(0.07)	(–0.62)	(0.30)	(0.18)
Dispositions	0.05***	0.04**	0.00	–0.01
	(2.85)	(2.03)	(–0.12)	(–0.29)
Production	–0.56***	–0.51***	–0.26**	–0.26**
	(–5.84)	(–5.95)	(–2.36)	(–2.48)
Recoveries	0.08	0.05	0.04	0.04
	(0.74)	(0.52)	(1.14)	(1.05)
Revisions	–0.08***	–0.07***	–0.03*	–0.03**
	(–6.47)	(–6.29)	(–1.90)	(–2.00)
Percent_NatGas	–0.07***	–0.08***	–0.05*	–0.05*
	(–3.19)	(–3.37)	(–1.81)	(–1.83)
Derivatives	–0.05***	–0.05***	0.01	0.01
	(–3.18)	(–3.79)	(1.11)	(0.92)
Investment	–0.04*	–0.06*	–0.06***	–0.06***
	(–1.83)	(–1.92)	(–2.96)	(–3.14)
Year Fixed Effects	YES	YES	YES	YES
Firm Fixed Effects			YES	YES
Adj. R^2	27.70%	31.24%	68.77%	68.92%
F-test for equality of R^2	$R^2(1) - R^2(2)$: p-value = 0.037		$R^2(3) - R^2(4)$: p-value = 0.232	

This table presents evidence on the determinants of disclosed dispersion of O&G reserves. Results are based on a sample of 1,156 Canadian O&G firm-years from 2004 to 2011. The table presents regression summary statistics from estimating the relation between the disclosed dispersion of reserves and the determinant variables. See Appendix C for variable definitions. *t*-statistics (in parentheses) are based on standard errors clustered by firm and year. *, **, and *** denote significance at the 10%, 5%, and 1% levels.

Table 8
Disclosures of Reserves Dispersion and Future Reserves

Panel A. Reserves Revisions

	Dependent Variable: *Future_Negative_Revisions*					
	1-year horizon		2-year horizon		3-year horizon	
Explanatory Variables	(1)	(2)	(3)	(4)	(5)	(6)
Reserves_Dispersion	–0.03	–0.23*	–0.02	–0.08	0.12	0.24
	(–0.27)	(–1.69)	(–0.17)	(–0.41)	(1.02)	(0.99)
General_Controls	YES	YES	YES	YES	YES	YES
O&G_Controls	YES	YES	YES	YES	YES	YES
Lag_Dep_Variable	YES	YES	YES	YES	YES	YES
Year Fixed Effects	YES	YES	YES	YES	YES	YES
Firm Fixed Effects		YES		YES		YES
Adj. R^2	2.47%	11.77%	4.72%	10.67%	3.42%	10.49%

Panel B. Future Reserves

	Dependent Variable: *Log_Future_Reserves*				
Explanatory Variables	(1)	(2)	(3)	(4)	(5)
Reserves_Dispersion	1.27***	1.00***	0.14	0.11	0.29
	(3.98)	(3.40)	(1.44)	(1.11)	(0.84)
General_Controls	YES	YES	YES	YES	YES
O&G_Controls		YES	YES	YES	YES
Lag_Dep_Variable			YES	YES	YES
Year Fixed Effects				YES	YES
Firm Fixed Effects					YES
Adj. R^2	81.94%	85.35%	94.14%	94.53%	95.86%

This table presents evidence on the association between disclosures of reserves dispersion and future performance. Panel A presents determinants of future negative revisions of P50, i.e., the median of the estimated distribution of O&G reserves. Panel B presents determinants of the size of the reserves in the following year. *Future_Negative_Revisions* is an indicator variable that equals one if the technical revisions for P50 reported in year $t+s$ are negative, and zero otherwise; t is the current year and s = 1, 2, or 3 years depending on the test. *Log_Future_Reserves* is the logarithm of P50 of the reserves reported in year t+1. Results are based on a sample of 1,156 Canadian O&G firm-years from 2004 to 2011. Non-missing observations for the dependent variables in the 1-year, 2-year, and 3-year horizon tests are 886, 675, and 491. *General_Controls* and *O&G_Controls* are as in table 2. See Appendix C for variable definitions. *Lag_Dep_Variable* is the lagged dependent variable. t-statistics (in parentheses) are based on standard errors clustered by firm and year. *, **, and *** denote significance at the 10%, 5%, and 1% levels.