AN EXAMINATION OF THE VALUE-RELEVANCE OF OIL AND GAS RESERVE QUANTITY DISCLOSURES

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CHAPTER I

INTRODUCTION AND STATEMENT OF PURPOSE

One of the inherent difficulties in accounting for oil and gas firms has been the proper valuation and presentation of oil and gas reserves. Since the late 1970s, publicly traded oil and gas firms have been required to provide estimates of their proven[1] oil and gas reserves. These estimates are currently required, as unaudited supplementary disclosures, by Statement of Financial Accounting Standard (SFAS) No. 69, "Disclosures about Oil and Gas Producing Activities."

Controversy has surrounded these supplemental disclosures and industry experts have suggested that reserve disclosures have limited usefulness. The focus of the objections has not been on the conceptual validity but on the imprecision of the measurement. For example, "DeGolyer and MacNaughton state its opinion that it is at least five years after discovery before quantity estimates can be made within ± 20 percent error range" (Connor, 1979; p. 95). Proponents argue that traditional historical cost methods are limited in their ability to provide information about oil and gas producing activities and that the supplemental disclosures provide useful information to financial statement users. Recently, the importance of these disclosures was an issue with the Security Exchange Commission (SEC) regarding Securities Act Release (SAR) 6879,

[1] The terms "proven" and "proved" are used interchangeably in the accounting literature. For consistency, the term "proven" is used throughout this dissertation.

"Multijurisdictional and Modification to the Current Registration and Reporting System for Canadian Issuers."

> Some commenters were of the opinion that differences between U.S. and Canadian GAAP are sufficient to warrant reconciliation. Segment and supplemental oil and gas disclosures in accordance with U.S. GAP were cited specifically as reasons to require reconciliation. (SAR 6879, psyched)

The purpose of this dissertation is to study the relationship between "Disclosures about Oil and Gas Producing Activities, " as required by SFAS No. 69, and the market value of oil and gas firms. The primary focus of this research is to determine if reserve quantity disclosures contain value-relevant information that goes beyond earnings and book values.

Clinch and Magliola (1992) and Spear (1994a) provide the only empirical evidence on the information content of reserve quantity disclosures. Clinch and Magliola (1992) found that the reserve quantity disclosures were only value-relevant after controlling for either the average absolute revision, the average revisions, or the ratio of proven developed to proven reserves. Spear (1994a) found that disaggregating the net change of proven reserve quantity into its components conveyed additional information beyond that contained in the net change in total proven reserves itself. This study extends the work of Clinch and Magliola (1992), Spear (1994a) and other studies that have examined the value-relevance of reserve disclosure data in several areas.

First, previous studies controlled for other value-relevant information by using a book value only model (Harris and Ohlson, 1987), an earnings only model (Doran, Collins, and Dhaliwal, 1988; Kennedy and Hyon, 1992; and Alciatore, 1993) or did not control for other value-relevant information when examining the value-relevance of reserve disclosure data (Spear, 1994a). Recent studies (e.g., Easton and Harris, 1991 and Wild, 1992) provide market-wide evidence that both earnings and book values contain information relevant in explaining stock prices. This study uses Ohlson's (1991) model to provide a framework within which to examine the value-relevance of reserve disclosure data. Ohlson's model relates firm value to accounting earnings, book value of equity, and other value-relevant information. Other information is considered value-relevant if it is useful in predicting future earnings.

Second, this study looks at the value-relevance of proven developed and proven undeveloped reserves. In addition, the analysis of the study is performed using both an energy-based method and a revenue-based method to convert proven reserves of gas to oil as well as doing the analysis without combining proven reserves of gas and proven reserves of oil. Previous studies have only performed their analysis by combining proven reserves of gas and proven reserves of oil using an energy-based method.

Finally, the study extends previous research on the valuation of oil and gas firms by examining the value-relevance of a firm's effort and ability to discover and extend proven reserves. Magliolo (1986) suggested that the market anticipates the discovery of new reserves. Therefore, it is possible that the effort exerted and the ability to discover proven reserves are important factors in valuing oil and gas firms. Hypotheses were developed to test whether effort and ability were important factors. In these tests, exploratory costs served as a surrogate for effort and new additions of proven reserves due to discoveries and extensions divided by exploratory costs served as a surrogate for ability.

Regression models were estimated to test the hypotheses. To estimate these regression models cross-sectional accounting data from 1990 to 1993 was pooled across-time. Results suggest that proven reserves are value-relevant. However, when proven reserves of gas and proven reserves of gas are not combined proven reserves of gas are value-relevant for full cost (FC) firms and proven reserves of oil are value relevant for successful effort (SE) firms. In addition, proven developed reserves are value-relevant while proven undeveloped reserves are not. The results also suggest that effort and ability are important factors for valuing oil and gas firms. Finally, the results suggest that effort and ability are more important than proven reserves in place at time *t* for valuing FC firms while proven reserves in place at time *t* are more important than effort and ability for SE firms.

The following chapter presents a review of the literature. Chapter III describes the empirical framework and develops hypotheses. A description of the research design and sample selection process are presented in Chapter IV, followed by a discussion of test results in Chapter V. The last chapter (VI) presents a summary and discusses the results of the study.

CHAPTER II

LITERATURE REVIEW

Since the issuance of Accounting Series Release (ASR) No. 253, "Adoption of Requirements for Financial Accounting and Reporting Practices for Oil and Gas Producing Activities," numerous studies have examined the reliability or the relevance of reserve disclosure data. Studies which investigated the value-relevance of reserve disclosures are reviewed here. Campbell (1988) and Alciatore (1990) provide a review of studies that examine the reliability of reserve disclosures.

The remainder of this literature review is organized as follows. Section 2.1 discusses studies that specifically addressed the value-relevance of reserve-quantity disclosures. Section 2.2 reviews association studies that examined the incremental information content of reserve-value disclosures with respect to firm value. Section 2.3 contains a review of other studies that have examined reserve disclosure data. Finally, section 2.4 presents a summary and a critique of these studies.

2.1 Reserve-Quantity Disclosure Studies

Clinch and Magliolo (1992) explored two empirical questions. First, given a benchmark estimate of reserves based on a firm's current production levels, were reserve quantities value-relevant? Second, did the association between market valuation and a firm's reserve value disclosures differ across firms according to characteristics of disclosed data? Based on Hotelling's (1931) work, Clinch and Magliolo developed a theoretical link between a firm's oil reserves and firm value. This link was then restated in the weekly change in oil prices. Two further assumptions led to an empirical model which contained an estimate of the oil price response coefficient. To find the degree of the market's perceptions, this coefficient was regressed on firm-specific disclosures. The results from a sample of 86 firms, for the years 1984 to 1987, indicated that the reserve quantity disclosures were value-relevant. However, this value-relevance was not consistent across firms. Average absolute revisions, average revisions, and the ratio of proven developed to proven reserves all interact significantly with proven reserves.

Spear (1994a) examined the information content of the components of the annual changes in the quantity of proven reserves: 1) extensions, new discoveries, and improved recovery; 2) production; 3) net purchases of proven reserves; and 4) revisions of prior quantity estimates. The study examined the contemporaneous associations between unexpected returns and the unexpected portion of each of the components of the change during the release week of annual reports or forms 10K from 1884 to 1988. Expectation models were developed to estimate the unexpected portion of the components. The empirical results suggested that desegregating the net change in the quantity of proven reserves into its components conveys additional information beyond that contained in the net change in total proven reserves itself. Results also indicated that discoveries were highly associated with security returns even after controlling for production, and that revisions, net purchases, and production have a modest influence on security returns.

2.2 Reserve-Value Disclosure Studies

Harris and Ohlson (1987) examined the significance of reserve-value measures in explaining the market value of oil and gas properties. The analysis covered the years 1979-1983 with the number of sample firms varying from 49 to 62 for a total of 282 data points. A cross-sectional multivariate regression model, with the imputed value of oil and gas properties as the dependent variable, was estimated for each year. The imputed value of oil and gas properties was calculated as the market value of equity plus the value of liabilities (market value was used for debt, book value for other liabilities) minus the book value of non-oil and gas assets. Harris and Ohlson concluded that proven reserve quantities did not significantly contribute to the explanation of the imputed market value when the book value and present value of future net cash flows were available. An additional finding was that the market clearly distinguishes between successful-efforts and full-cost firms.

Doran, Collins and Dhaliwal (1988) tested for the incremental information content of value-based measures of reserves, relative to historical cost earnings using cross-sectional regression models pooled over the test period. The test period included the years 1979-81 for RRA measures and the years 1982-84 for SFAS No. 69 measures. The dependent variable was cumulative abnormal returns (CAR) estimated using the market model. Independent variables included the change in net income, present value of future net revenues due to discoveries, the present value of future net revenues due to price and quantity revisions, the total change in the present value of revenues resulting from sales and purchases, and RRA net income. The results for the RRA period indicated that the following have incremental information content: the present value of future net revenues due to discoveries, the present value of future net revenues due to price and quantity revisions, and RRA net income. However, with only the present value due to price and quantity revisions significant, the SFAS No. 69 period results were weaker than those of the RRA. In addition, results were stronger for producing firms than for refining firms.

Kennedy and Hyon (1993) employed a regression model and an insider trading model to evaluate whether the component values of RRA improved the extent to which reported earnings reflected factors affecting stock prices. The regression model was similar to that of Doran *et al.* (1988) with CAR as the dependent variable. Independent variables included net income, additions to proven reserves, additions and revisions to proven reserves over evaluated costs, and results of oil and gas producing activities on the basis of RRA. Each RRA variable was regressed by itself with only net income in the model. All RRA variables were found to be significant. The insider trading model results also supported the usefulness of RRA disclosure.

Finally, Alciatore (1993) investigated the information content of the change in the standardized measure (CSM) disclosures required under SFAS No. 69. Using CAR as the dependent variable, cross-sectional regression models were pooled over a test period of 1982 to 1984. Unlike previous studies, the sample excluded Canadian firms. Results indicated that the CSM had no incremental information content unless separated into its individual components. When divided into its individual components, the following six (of the ten) components of CSM provided incremental information relative to the other components and to net income: (1) production, (2) discoveries, (3) purchases of reserves, (4) quantity revisions, (5) price changes, and (6) the change in income taxes.

2.3 Other Capital Market Studies

This section contains a review of other capital market studies that have examined reserve disclosure data. The studies were important because they contain information concerning the value-relevance of reserve disclosure data; however, they were placed in this section for one or more of three reasons: first, the study did not address the incremental information content of reserve disclosure; second, the study was not an association study; and third, the main purpose of the study was not the value-relevance of reserve disclosure data.

Bell (1983) used event study methodology to examine whether reserve disclosures provide relevant information. Using a modified market model that included an industry index to control for industry effects during the disclosure period, Bell (1983) tested abnormal returns around the release of the initial reserve recognition accounting (RRA) disclosures. The sample consisted of 51 oil and gas firms that filed RRA data in 1978 after their 10Ks were filed. The results of Bell's study supported the hypothesis of significant stock market reaction to RRA disclosures.

Under the assumption that knowledge was costless, Dharan (1984) developed three increasingly complex specifications of expectation models by transforming other concurrently available non-RRA data. His premise was that for RRA disclosures to have incremental information content, the RRA data cannot be derived from other available sources. Strong linear relationships between actual RRA data and the models were uncovered, implying that RRA signals have potentially low incremental information content in the sense that they may not have much incremental impact on observed security prices.

Using a valuation model, Magliolo (1986) did a capital market study of reserve value disclosures. This model, in which oil and gas firms were valued according to their oil and gas reserves, was based on the Hotelling Principle used by Miller and Upton (1985a, 1985b). Cross-sectional regressions, estimated separately for each year (1979-83), were used to test the hypothesized relationships in two sets of tests. The imputed market value of a firm's oil and gas operations was compared to its RRA reserve value in the first set of tests. The second set of tests examined whether future discoveries of reserves and changes in RRA reserve values were associated with changes in the firm's oil and gas operations. Results indicate that the RRA variables did not measure market values nor changes therein of the firm's oil and gas operations according to the model's predictions. Extended tests did indicate that RRA income statement data were associated with market value.

Ghicas and Pastena (1988) focused on the ability of publicly available information, including oil and gas reserves, to determine the acquisition value of oil and gas firms. Cross-sectional regression models, pooled over the period 1979-87, were used to compare the explanatory ability of the independent variables for a sample of 44 firms. Independent variables included the book value of oil and gas assets, the book value of non oil and gas assets, the direct profit margin, the present value of net cash flows associated with proven reserves, and the Herold appraised value of the firm. The results from the regression analysis indicated that when all historical cost variables, oil and gas assets and book value of non-oil and gas assets, and the reserve value variable were included in one model, the book value of the oil and gas assets and the reserve value variables were significant. However, when the Herold's appraisal variable was added, it was significant, but the two accounting book value variables became insignificant. Further analysis indicated that a timing advantage existed for the analysts' appraisals.

The results of Harris and Ohlson (1987) were investigated by Harris and Ohlson (1990) to determine if they occurred because investors were functionally fixated on book values or if the book values were significant because of their value-relevance. To address this question, Harris and Ohlson (1990) used zero-investment trading rules based on portfolios constructed from the imputed market value (per equivalent barrel of proven reserves). If the security market was informationally efficient, this trading rule would not yield systematic positive returns and such a result would suggest that book values were value-relevant. The trading rule based on cross-sectional variation in the inferred market values yielded significant positive returns that could not be explained by portfolio risk. This suggested a market inefficiency with functional fixation on the book values being one possibility. To test for functional fixation, another trading rule was created which controlled for the book value component of the inferred market value.

This second trading rule provided even larger returns than the first, which contradicts the simple form of functional fixation. To finally conclude against functional fixation, the researchers tested a trading rule that controlled for other information, including supplementary information from the required reserve value disclosures. These trading rules yielded significant results, but did not improve on the results from the trading rule that controls for book value. In conclusion, the results of the paper complement those reported by Harris and Ohlson (1987) and did not attribute the relationship between book value of oil and gas properties to functional fixation. In combination, the results suggested that although a pricing anomaly existed for the sample, the anomaly could not be ascribed to functional fixation on book values.

Reserve-based present-value disclosures were evaluated for a sample of oil and gas producing firms by Raman and Tripathy (1993) to test the effect of the disclosures on the informed trading component of bid/ask spreads. The average spread was compared before and after the release of the 10K reports. If the public disclosure of supplemental reserve data in the 10K had the effect of reducing the informed trading component of the spread, the change in the spread (over and above that explained by changes in inventory-holding and order processing variables) should have been related empirically to the magnitude of the absolute values of the reserve variables with an anticipated negative sign. Results indicated that the present value of estimated net revenues resulting from new discoveries and extensions of proven reserves was significant in explaining the change in the bid/ask spread. As anticipated, the change in net income was not significant. This result was anticipated because of the release of net income information prior to the 10K report date.

Finally, Shaw and Wier (1993) sampled firms from the oil and gas industry to determine whether organizational choice affected the market value of firms. The two organizational choices were master limited partnerships (MLPs) and corporations. They extended Harris and Ohlson's (1987) valuation model by adding variables for dividends and exploration levels. Exploration levels were found significant for both MLPs and corporations, but dividends were relevant for MLPs only. The coefficient for the present value of future net cash flows from proven reserves was significant for MLPs.

2.4 Summary and Critique

In summary, evidence supported the incremental information content of reserve disclosure data. The studies of Clinch and Magliolo (1992) and Spear (1994) provided evidence to support the information content of reserve-quantity disclosures, while those of Harris and Ohlson (1987), Doran *et al.* (1988), Kennedy and Hyon (1993), and Alciatore (1993) provided evidence to support the value-relevance of reserve-value disclosure.

Previous studies, however, failed to address several concerns. First, they fail to control for other value-relevant information. They assumed a book-value-only model (Harris and Ohlson, 1987) or an earnings-only model (Doran *et al.*, 1988; Kennedy and Hyon, 1992; and Alciatore, 1993) or did not control for information contained in the primary financial statements (Spear, 1994). Recent studies, Easton and Harris (1991) and Wild (1992) used a market-wide sample and demonstrated that both earnings and book values provide information relevant in explaining stock prices. In addition, Shaw and Wier (1993) provided evidence that exploratory costs are value-relevant.

A second problem with previous studies was that measurement error may have existed in the dependent variable. Harris and Ohlson (1987) used the imputed market value of oil and gas assets as their dependent variable. This variable was calculated as the market value of equity plus liabilities minus non-oil and gas assets. This calculation assumed that only oil and gas assets affect the difference between market value and book value of the firm. Also, it did not exclude the value of liabilities that are attached to non-oil and gas assets.

Errors in measuring the variables also seem apparent in studies using cumulative abnormal returns as the dependent variable. Such errors could have been the result of using the wrong model to estimate the abnormal returns. An indication of this type of model mispecification appeared in Alciatore (1993), where the most significant explanatory variable is the year.

Limitations with the data was also a problem in prior studies. First, the studies used relatively short time periods in their analyses. However, Harris and Ohlson (1987) and Doran *et al.* (1988) found evidence that reserve disclosure data was not consistent over time. Second, the studies combined oil and gas reserves using an energy-based conversion. Lys (1986) and Koester (1993) suggested that a revenue-based conversion may be more appropriate.

CHAPTER III

EMPIRICAL FRAMEWORK AND HYPOTHESES DEVELOPMENT

Ohlson's (1991) model provides a framework in which to examine the incremental information content of reserve disclosures. This model relates the value of the firm to the information provided in the income statement (earnings), the balance sheet (book value of equity), and other value-relevant information. Both accounting earnings and book value of equity are relevant in Ohlson's model because they assist in predicting future dividends, the theoretical basis for a firm's market value.[2] The use of other value-relevant information in the model is motivated by the idea that many currently observable value-relevant events can affect future (expected) earnings in addition to current earnings.

3.1 Valuation Model

Ohlson (1991) assumes a risk-neutral economy with homogeneous beliefs and a non-stochastic flat term structure of interest rates. Thus the market value of the firm is equal to the present value of future dividends.

[2] Berry, Teall, and Brown (1993) provide supplementary evidence that valuing oil and gas firms using earnings and book value is appropriate. A survey of analysts that study oil and gas firms revealed that both an earnings method and an asset valuation method were used by American analysts.

Assumption (A1)

$$MV_t = \sum_{\tau=1}^{\infty} R_F^{-\tau} E_t[\tilde{d}_{t+\tau}] \quad (1)$$

where

MV_t = the market value, or price, of the firm at date t.

d_t = dividends paid at date t.

R_F = the risk-free rate plus 1.

$E_t[.]$ = the expected value operator conditioned on the date t information.

In order to provide conceptual linkages between current and future anticipated accounting data and how such data relate to market value, let

x_t = earnings for the period (t-1, t)

and

y_t = (net) book value at date t.

Next assume that the change in the book value between two dates equals earnings minus dividends, i.e. the clean surplus stock/flow reconciliation must be satisfied. This is formally stated as follows:

Assumption (A2a)

$$y_{t-1} = y_t + d_t - x_t \quad (2)$$

It is also assumed that the payment of dividends reduces book value, but not current earnings.

Assumption (A2b)

$$\partial y_t / \partial d_t = -1 \quad (3)$$

$$\partial x_t / \partial d_t = 0 \quad (4)$$

Applying the clean surplus relations allows MV_t to be expressed in terms of book value and earnings. First, define abnormal earnings, x^a_t, as follows:

$$x_t^a = x_t - (R_F - 1)y_{t-1} \tag{5}$$

and then use the clean surplus relation to substitute $y_t + d_t - y_{t-1}$ for x_t to obtain

$$x_t^a = y_t + d_t - R_F y_{t-1} \tag{6}$$

Now substituting $d_\tau = x^a_t + R_F y_{\tau-1} - y_\tau$ into (A1) for $\tau = t, t+1,...$

yields

$$MV_t = y_t + \sum_{\tau=1}^{\infty} R_F^{-\tau} E_t[\tilde{x}^a_{t+\tau}] \tag{7}$$

To allow a role for information other than current abnormal earnings for predicting future abnormal earnings an assumption concerning the time-series behavior of abnormal earnings is added.

Assumption (A3)

Assume $\{x^a_{t+\tau}\}\tau > 1$ satisfies the stochastic process

$$\tilde{x}^a_{t+1} = \omega x_t^a + v_t + \tilde{\epsilon}_{1t+1} \tag{8}$$

$$\tilde{v}_{t+1} = \quad + \gamma v_t + \tilde{\epsilon}_{2t+1} \tag{9}$$

where v_t represents other information available at time t, and the disturbance terms, ϵ_{1t+1} , ϵ_{2t+1}, $\tau > 1$, are zero mean, random variables given the information at date t (x^a_t, v_t). The parameters of the process, ω, and γ, are fixed and known and can be interpreted as persistence parameters.

The valuation function is derived from assumptions (A1), (A2a) and (A3).

$$MV_t = y_t + \alpha_1 x_t^a + \alpha_2 v_t \tag{10}$$

where

$$\alpha_1 = \omega/(R_F - \omega) \geq 0 \tag{11}$$

$$\alpha_2 = R_F/(R_F - \omega)(R_F - \gamma) > 0 \tag{12}$$

This result, as derived by Ohlson (1991), is demonstrated in Appendix A1.

Given the definition of abnormal earnings, (10) can be restated as follows:

$$MV_t = y_t + \alpha_1 x_t - \alpha_1(R_F - 1)y_{t-1} + \alpha_2 v_t \tag{13}$$

This equation indicates that the market value of the firm at time *t* can be explained by its book value at time *t*, its earnings at time *t*, its book value at time *t* - 1, and other value-relevant information. Other information is considered value-relevant if it provides information about the future earnings of the firm. If the information is positively associated with future earnings, then it is positively associated with the market value of the firm.

In this study reserve quantity and exploratory cost disclosures are used to provide two additional sources of information concerning future earnings. First, the future earnings that result from the production and sale of proven reserves in place at time *t*. Second, the future earnings that result from the production and sale of new additions of proven reserves due to discoveries and extensions after time *t*. Discoveries include the discovery of proven reserves in an area not previously defined as proven and the discovery of another reservoir in an area already defined as proven. Extensions add additional acreage to an existing proven reservoir.

3.2 Proven Reserves in Place

The first two hypotheses relate to the value relevance of proven reserve quantities. Proven reserves in place at time t, can be associated with future earnings, as illustrated by the Hotelling Valuation Principle (HVP), developed by Miller and Upton (1985a, 1985b). The HVP assumes that the owner of an exhaustible resource is both a profit-maximizer and a price-taker. The resource may be extracted in the current period or in any of the next N periods. Then let q_0, q_1, ..., N be the amount of the resource extracted at time t = 0, 1, ..., N. Assuming that extraction costs, c_0, are initially taken to be constant, the present value of profits, V_0, can be stated as follows:

$$V_0 = \sum_{t=0}^{N} (p_t - c_0) q_t / (1 + r)^t \tag{14}$$

where p_t is the exogenously given market price of output at time t, and r is the discount rate. Both are assumed known and constant over time. N is a known date beyond which production can safely be presumed to have ceased. V_0 is maximized subject to the constraint

$$\sum_{t=0}^{N} q_t \leq R_0 \tag{15}$$

where R_0 are total reserves at time 0. The first-order condition[3] for profit maximization in any period is

$$(p_t - c_0)/(1 + r)^t = \lambda, \qquad t=0,\ldots,N \tag{16}$$

[3] See Appendix A2 for a derivation of the first-order conditions.

where λ is the lagrange multiplier on the constraint (15). The present value of the net unit price of output must be the same regardless of when it is produced. This leads to the Hotelling Pricing Principle:

$$(p_t - c_0) = (p_0 - c_0)(1 + r)^t, \qquad t=0,\ldots,N \tag{17}$$

and by substituting (7) into (4) leads to the HVP,

$$V_0 = (p_0 - c_0)\sum_{t=0}^{N} q_t = (p_0 - c_0)R_0. \tag{18}$$

This result implies that the present value of future profits (earnings) from proven reserves in place, after controlling for price and extraction costs, is positively related to proven reserves. In Ohlson's model, information that is positively related to future profits (earnings) is positively related to the market value of the firm. This leads to the first hypothesis stated in the alternative form.

> H_{A1}: Given price and extraction costs, the market value of the firm is positively related to proven reserves.

Proven reserves can be further divided into proven developed reserves and proven undeveloped reserves. Proven developed reserves are reserves which can be expected to be recovered through existing wells. Proven undeveloped reserves are reserves which are expected to be recovered from new wells on undrilled acreage, or from existing wells where a relatively major expenditure is required for recompletion (SFAS No. 19, par. 271). This means that the extraction costs for proven developed reserves are equal to the producing (lifting) costs of the reserves. Extraction costs for proven undeveloped reserves include both producing (lifting) costs and development costs. This results in the per-barrel extraction costs being less for proven developed reserves than for proven undeveloped reserves. Because of this difference in extraction costs between proven developed reserves and proven undeveloped reserves, the quantity of proven reserves alone does not describe the relationship between proven reserves, earnings, and market value of the firm. Whether the proven reserves are developed or undeveloped must also be considered. This results in the second and third hypotheses stated in the alternative form.

H_{A2}: The market value of the firm is positively related to proven developed reserves.

H_{A3}: The market value of the firm is positively related to proven undeveloped reserves.

3.3 Future Discoveries and Extensions of Proven Reserves

The next two hypotheses relate to a firm's future discoveries and extensions of proven reserves. Future discoveries and extensions of proven reserves can be summarized by the following function:

$$R_{FD} = f(E,A) \tag{19}$$

where R_{FD} is the future discoveries and extensions of proven reserves, E is the effort exerted by the firm to discover or extend proven reserves and A is the ability (effectiveness) of the firm to discover or extend proven reserves.

Assuming diminishing returns to scale, a change in future discoveries or extensions with respect to a change in effort is increasing at a decreasing rate, $f'(E) > 0$ and $f''(E) < 0$. Similarly a change in future discoveries or extensions with respect to a change in ability is increasing at a decreasing rate, $f'(A) > 0$ and $f''(A) < 0$. This is consistent with the work of Arps, Mortada, and Smith (1971) regarding the relationship between proven reserves and exploratory effort. Under the assumption that a firm does not extend effort beyond the point where marginal benefits equal marginal costs, an increase in effort implies an increase in future discoveries and extensions of proven reserves, which in turn produces future earnings. In Ohlson's model, information that is positively related to future earnings is positively related to the market value of the firm. This lead to the third hypothesis stated in the alternative form.

H_{A4}: The market value of the firm is positively related to effort.

Effort alone is not a sufficient condition to distinguish a firm's success at finding future discoveries and extensions of proven reserves. The ability of a firm to find proven reserves must also be considered. Given a level of exploratory effort, an increase in a firm's ability implies an increase in discoveries and extensions of proven reserves, which in turn increases future earnings. The implication is that a firm's ability to find reserves affects the relationship between a firm's effort and earnings, and in turn, the market value of the firm. As ability increases, the change in MV due to a change in effort becomes larger. This lead to the fourth hypothesis stated in the alternative form.

H_{A5}: The change in market value of the firm due to a change in effort increases as the ability to discover and extend proven reserves increases.

CHAPTER IV

RESEARCH DESIGN AND SAMPLE SELECTION

This chapter is organized as follows. First, the research design is discussed. In this discussion the regression models are introduced, the test variables are defined and the testing procedures are described. This section also includes a discussion of the specification tests and regression diagnostics that were performed as well as any additional analysis done to mitigate any problems discovered. Second, the sample and its selection process are discussed.

4.1 Research Design

The research design consisted of estimating regression models using a sample of oil and gas firms. To estimate these regression models cross-sectional accounting data from 1990 to 1993 was pooled across time (panel data). Dummy variables were used to control for information specific to each year. The dependent variable was stock price per share and all independent variables were expressed on a per share basis. Ohlson's (1991) model indicated that the market value of the firm at time t was explained by its book value at time t, its earnings at time t, its book value at time t - 1 and other value relevant information. Therefore, book value per share at time t (y_t), earnings per share at time t (x_t) and book value per share at time t - 1 (y_{t-1}) were used as control variables.

There are two different permissible accounting methods in the oil and gas industry, the full cost (FC) and the successful efforts (SE) methods. Under the FC method a firm capitalizes all exploratory costs and amortizes these costs over the discovered reserves on a pro rata basis. Under the SE method, a firm capitalizes only those prediscovery costs that can be related directly to revenue-producing wells. The SE method has been recognized as being more conservative than the FC method. Bandyopadhyay (1994) and Harris and Ohlson (1987) provide evidence that the market not only distinguishes between FC and SE firms, but also that SE was the more conservative of the two methods. In addition, Malmquist (1990) found that the choice of accounting methods depended upon certain firm characteristics. To control for the different accounting methods and the related firm characteristics, the regression models were also estimated using first only FC firms, and then only SE firms.

4.1.1 Regression Models

Regression models 1 and 2 used the combined proven reserve quantities of oil and gas; therefore, it was necessary to calculate barrels of oil equivalent (BOEs). BOEs were initially calculated using the standard BTU conversion: one barrel of crude oil equals six MCFs of natural gas (BOEs-energy). Combining proven reserves of oil and proven reserves of gas using an energy-based conversion was consistent with prior studies (i.e., Clinch and Magliola, 1992 and Spear, 1994) and with the requirements of the reserve-value disclosure. Thus, using BOEs-energy to estimate the models allows the results to be compared to those of other reserve disclosure studies.

The validity of the energy-based conversion has been questioned in the accounting literature (Lys, 1986; Koester, 1993). It was chosen for the preparation of the reserve-value disclosure at a time when oil and gas prices were regulated. Because of this regulation, the economic relation between oil and gas was considered artificial (SFAS No. 19, par. 214). However, oil and gas market prices are no longer regulated and their economic relation may be vastly different. Therefore, the first two regression models were also estimated using a revenue-based conversion method to calculate BOEs (BOEs-revenue). BOEs-revenue were calculated by multiplying proven reserves of gas by the ratio of the average price of natural gas for firm *i* at time *t* to the average price of crude oil for firm *i* at time *t*.

Regression model 1 was used to test hypotheses 1, 4 and 5. It was estimated as follows:

$$P_{it} = \alpha_0 + \alpha_1 D1 + \alpha_2 D2 + \alpha_3 D3 + \delta_1 y_{it} + \delta_2 x_{it} + \delta_3 y_{it-1} + \theta_1 R_{it} + \theta_3 E_{it} + \theta_4 E*A_{it} + \epsilon_{it} \qquad \textbf{(20)}$$

Where

P_{it} = stock price per share for firm *i* at time *t*,

D1= a dummy variable; 1 if the year is 1990, 0 otherwise,

D2= a dummy variable; 1 if the year is 1991, 0 otherwise,

D3= a dummy variable; 1 if the year is 1992, 0 otherwise,

y_{it} = (net) book value per share for firm *i* at time *t*,

x_{it} = earnings per share for firm *i* at time *t*,

y_{it-1} = (net) book value per share for firm *i* at time *t* - 1,

R_{it} = total proven reserves per share for firm *i* at time *t*,

E_{it} = the effort exerted by firm *i* for the period *t* - 1 to *t*,

A_{it} = the ability of firm *i* at time *t* to discover or extend proven reserves,

ϵ_{it} = the error term.

Hypothesis 1 stated that given price and extraction costs, the market value of the firm was positively related to proven reserves; therefore, the coefficient on proven reserves (*R*) in regression model 1 was predicted to be positive, $\theta_1 > 0$. Proven reserves were defined as the total proven reserves, proven developed and proven undeveloped reserves, that firm *i* had as of time *t*.

The fourth hypothesis stated that that the market value of the firm was positively related to effort (*E*). Exploration costs which was included in the Cost Incurred section of the SFAS No. 69 disclosures, was chosen as a surrogate for *E*. Using exploration costs as a surrogate for *E* was consistent with the conclusion of the FASB to continue to disclose such costs (SFAS No. 69, par. 89). *E* was defined as those costs incurred by firm *i* for the period *t* - 1 to *t* in identifying areas that might warrant examination and in examining specific areas.[4] *E* included those costs that were capitalized or charged to expense at the time they were incurred (SFAS No. 69, par. 21). The fourth hypothesis predicted that the coefficient on *E* was positive, $\theta_3 > 0$.

The fifth hypothesis stated that the change in market value of the firm due to a change in effort increases as the ability to discover and extend proven reserves (*A*) increases. Testing this hypothesis involved interacting *E* and *A*. A surrogate for *A* was created by dividing new additions of proven reserves due to discoveries and extensions for a given period by the exploratory costs for that period. The larger this ratio, the

[4] See Appendix C, the glossary, for a more comprehensive definition.

higher the firm's ability to discover or extend proven reserves. According to hypothesis 5, the coefficient on E^*A was predicted to be positive, $\theta_4 > 0$.

To test hypothesis 2 and 3, proven developed reserves and proven undeveloped reserves were entered into the second regression model as separate variables. Regression model 2 was estimated as follows:

$$\begin{aligned} P_{it} = \alpha_0 + \alpha_1 D1 + \alpha_2 D2 + \alpha_3 D3 + \delta_1 y_{it} + \delta_2 x_{it} + \delta_3 y_{it-1} \\ + \theta_1 DR_{it} + \theta_2 UDR_{it} + \theta_3 E_{it} + \theta_4 E{*}A_{it} + \epsilon_{it} \end{aligned} \tag{21}$$

where

P_{it} = stock price per share for firm i at time t,

$D1$= a dummy variable; 1 if the year is 1990, 0 otherwise,

$D2$= a dummy variable; 1 if the year is 1991, 0 otherwise,

$D3$= a dummy variable; 1 if the year is 1992, 0 otherwise,

y_{it} = (net) book value per share for firm i at time t,

x_{it} = earnings per share for firm i at time t,

y_{it-1} = (net) book value per share for firm i at time t - 1,

DR_{it} = proven developed reserves per share for firm i at time t,

UDR_{it} = proven undeveloped reserves per share for firm i at time t,

E_{it} = the effort exerted by firm i for the period t - 1 to t,

A_{it} = the ability of firm i at time t to discover or extend proven reserves,

ϵ_{it} = the error term.

The second hypothesis, stated in the alternative form, was that the market value of the firm was positively related to proven developed reserves. Using regression model 2, this hypothesis predicted that the coefficients on proven developed reserves (*DR*) was positive, $\theta_1 > 0$. *DR* was defined as the proven developed reserves that firm *i* had as of time *t*. The third hypothesis stated that the market value of the firm was positively related to proven undeveloped reserves (*UDR*); therefore, the coefficient on *UDR* was predicted to be positive, $\theta_2 > 0$. *UDR* was defined as the proven undeveloped reserves that firm *i* had as of time. The second regression model also tested hypotheses 4 and 5. The variables, *E* and *A*, and the predictions, $\theta_3 > 0$ and $\theta_4 > 0$, were the same as those of the first regression model.

A possible explanation for weak results in previous studies was that calculating BOEs using either an energy-based or a revenue-based conversion method introduced error into the proven reserves variables. To control for this error, proven reserves of oil and proven reserves of gas were entered into regression models 3 and 4 as separate variables. Regression model 3 was estimated as follows:

$$P_{it} = \alpha_0 + \alpha_1 D1 + \alpha_2 D2 + \alpha_3 D3 + \delta_1 y_{it} + \delta_2 x_{it} + \delta_3 y_{it-1} + \theta_1 RO_{it} + \theta_2 RG_{it} + \theta_3 E_{it} + \theta_4 E{*}A_{it} + \epsilon_{it} \quad (22)$$

where

P_{it} = stock price per share for firm *i* at time *t*,

D1= a dummy variable; 1 if the year is 1990, 0 otherwise,

D2= a dummy variable; 1 if the year is 1991, 0 otherwise,

D3= a dummy variable; 1 if the year is 1992, 0 otherwise,

y_{it} = (net) book value per share for firm *i* at time *t*,

x_{it} = earnings per share for firm *i* at time *t*,

y_{it-1} = (net) book value per share for firm *i* at time *t* - 1,

RO_{it} = proven reserves of oil per share for firm i at time t,

RG_{it} = proven reserves of gas per share for firm i at time t,

E_{it} = the effort exerted by firm i for the period t - 1 to t,

A_{it} = the ability of firm i at time t to discover or extend proven reserves,

ϵ_{it} = the error term.

Similar to regression model 1, regression model 3 was used to test hypotheses 1, 4, and 5. When using the third regression model, hypothesis 1 predicted positive coefficients for proven reserves of oil (RO) and for proven reserves of gas (RG), $\theta_1 > 0$ and $\theta_2 > 0$, respectively. Because exploratory costs, the surrogate for effort (E), was not separately available for oil and gas activities, the variables and predictions for hypotheses 4 and 5, $\theta_3 > 0$ and $\theta_4 > 0$, were the same as for regression models 1 and 2.

Regression model 4 tested hypotheses 2, 3, 4 and 5. Proven developed reserves of oil, proven undeveloped reserves of oil, proven developed reserves of gas, and proven undeveloped reserves of gas were all entered into the model as separate variables. The fourth regression model was estimated as follows:

$$\begin{aligned} P_{it} = \alpha_0 &+ \alpha_1 D1 + \alpha_2 D2 + \alpha_3 D3 + \delta_1 y_{it} + \delta_2 x_{it} + \delta_3 y_{it-1} \\ &+ \theta_1 DRO_{it} + \theta_2 UDRO_{it} + \theta_3 DRG_{it} + \theta_4 UDRG_{it} \\ &+ \theta_5 E_{it} + \theta_6 E*A_{it} + \epsilon_{it} \end{aligned} \tag{23}$$

where

P_{it} = stock price per share for firm i at time t,

$D1$= a dummy variable; 1 if the year is 1990, 0 otherwise,

$D2$= a dummy variable; 1 if the year is 1991, 0 otherwise,

$D3$= a dummy variable; 1 if the year is 1992, 0 otherwise,

y_{it} = (net) book value per share for firm i at time t,

x_{it} = earnings per share for firm i at time t,

y_{it-1} = (net) book value per share for firm i at time t - 1,

DRO_{it} = proven developed reserves of oil per share for firm i at time t,

$UDRO_{it}$ = proven undeveloped reserves of oil per share for firm i at time t,

DRG_{it} = proven developed reserves of gas per share for firm i at time t,

$UDRG_{it}$ = proven undeveloped reserves of gas per share for firm i at time t,

E_{it} = the effort exerted by firm i for the period t - 1 to t,

A_{it} = the ability of firm i at time t to discover or extend proven reserves,

ϵ_{it} = the error term.

For regression model 4, hypothesis 2 predicted that the coefficients on proven developed reserves of oil (*DRO*) and proven developed reserves of gas (*DRG*) were both positive, $\theta_1 > 0$ and $\theta_3 > 0$, respectively. The third hypothesis predicted that the coefficients on proven undeveloped reserves of oil (*UDRO*) and proven undeveloped reserves of gas (*UDRG*) were both positive, $\theta_2 > 0$ and $\theta_4 > 0$, respectively. Similar to the previous three regression models, the fourth and fifth hypotheses predicted that the coefficients on E and $E*A$ were positive, $\theta_5 > 0$ and $\theta_6 > 0$, respectively.

To test the significance of the estimated coefficients, a t-test was performed for all the parameters estimated by all of the regression models. These t-tests were one-tailed for variables that were used to test the hypotheses and two-tailed for all other variables.

4.1.2 Specification Tests and Regression Diagnostics

This section discusses all of the specification tests and regression diagnostics performed and any additional analysis done to mitigate the problems discovered. First, all models estimated were tested to see if they violated the assumption of homoscedasticity. If this assumption was violated the ordinary least squares (OLS) estimator would no longer have been the best linear unbiased estimator (BLUE); however, the estimator would still have been consistent. The variance-covariance matrix which was required to perform hypothesis tests would have been inconsistent and as a result hypothesis tests could no longer have been trusted.

White's (1980) test for heteroskedasticity was performed. White's test is very general and does not require that specific assumptions about the nature of the heteroskedasticity be made. In addition, it tests specifically for whether or not any heteroskedasticity present causes the variance-covariance matrix of the OLS estimation to differ from its usual form. In cases where the assumption of homoscedasticity was violated White's (1980) heteroskedasticity-consistent covariance estimator was employed. Thus, proper inferences could be drawn from the hypothesis tests.

Second, to identify influential observations studentized deleted residuals (RSTUDENT) were used. An observation was considered influential if its associated RSTUDENT was greater than ±2.0. After identifying influential observations, they were removed from the data set and the regression models were estimated without them. Results without the influence data points, as identified by RSTUDENT, were the same as those with the influential observations. Therefore, the results reported were the estimations performed on data sets that included the influential observations and the generalizability of the results was preserved.

Finally, diagnostic procedures were performed to detect the presence of collinearity.[5] Highly correlated regressors create the possible occurrence of several problems. First, small changes in the data can produce wide swings in the parameter estimates. Second, coefficients may have high standard errors and low significance levels in spite of the fact that they are jointly significant and the R^2 in the regression is quite high. Third, coefficients will have the wrong sign or an implausible magnitude (Greene, 1990; p. 279). Therefore, there was both a bias against getting significance and an interpretation problem if collinearity was present.

Several approaches exist to diagnose the presence of collinearity. The first set relate to examining the correlation matrix.[6] Belsley, Kuh, and Welsch (1980) identify two problems with these approaches. First, a lack of a meaningful boundary to distinguish between values that can be considered high and those that can be considered low. Second, there is an inability to distinguish among several coexisting near dependancies. The implication of these two problems was that one can only conclude if collinearity was a problem, not if it did not exist.

The approach suggested by Belsley *et al.* (1980) to identify collinearity was the following double condition: 1) a singular value judged to have a high condition index (greater than 30) and which was associated with, 2) high-variance decomposition proportions for two or more estimated coefficient variances. This procedure was

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[5] The terms collinearity, multicollinearity, and ill conditioning are all used to denote this situation.

[6] The correlation matrices are shown, by model, in Appendix B.

performed and the results indicated that the book value per share at time t (y_t), the earnings per share at time t (x_t), and the book value at time $t-1$ (y_{t-1}) were correlated. Because hypothesis tests were not being performed on these variables this was not perceived as a problem. Additionally, none of these variables were found to be correlated with any of the variables of interest in any of the regression models estimated. However, variables that were used to test hypotheses related to proven reserves in place at time t, hypotheses 1, 2, and 3, were found to be correlated to those variables used to test hypotheses related to the future discovery and extension of proven reserves, hypotheses 4, and 5.

Additional analysis was performed because of the identified collinearity. This additional analysis involved estimating regression models that contained only those variables required to test either hypotheses 1, 2, and 3, or those variables used to test hypotheses 4 and 5. The first of these additional regression models, regression model 5, was as follows:

$$P_{it} = \alpha_0 + \alpha_1 D1 + \alpha_2 D2 + \alpha_3 D3 + \delta_1 y_{it} + \delta_2 x_{it} + \delta_3 y_{it-1} + \theta_1 R_{it} + \epsilon_{it} \qquad \textbf{(24)}$$

where

P_{it} = stock price per share for firm i at time t,

$D1$ = a dummy variable; 1 if the year is 1990, 0 otherwise,

$D2$ = a dummy variable; 1 if the year is 1991, 0 otherwise,

$D3$ = a dummy variable; 1 if the year is 1992, 0 otherwise,

y_{it} = (net) book value per share for firm i at time t,

x_{it} = earnings per share for firm i at time t,

y_{it-1} = (net) book value per share for firm i at time t - 1,

R_{it} = total proven reserves per share for firm i at time t,

ϵ_{it} = the error term.

This regression model was used to test the first hypothesis which predicted a positive coefficient on R, $\theta_1 > 0$. Again R was measured first in BOEs-energy and then in BOEs-revenue.

Regression model 6 was the second additional regression model estimated. It was used to test hypotheses 2 and 3 and was estimated as follows:

$$P_{it} = \alpha_0 + \alpha_1 D1 + \alpha_2 D2 + \alpha_3 D3 + \delta_1 y_{it} + \delta_2 x_{it} + \delta_3 y_{it-1} + \theta_1 DR_{it} + \theta_2 UDR_{it} + \epsilon_{it} \tag{25}$$

where

P_{it} = stock price per share for firm i at time t,

$D1$= a dummy variable; 1 if the year is 1990, 0 otherwise,

$D2$= a dummy variable; 1 if the year is 1991, 0 otherwise,

$D3$= a dummy variable; 1 if the year is 1992, 0 otherwise,

y_{it} = (net) book value per share for firm i at time t,

x_{it} = earnings per share for firm i at time t,

y_{it-1} = (net) book value per share for firm i at time t - 1,

DR_{it} = proven developed reserves per share for firm i at time t,

UDR_{it} = proven undeveloped reserves per share for firm i at time t,

ϵ_{it} = the error term.

The second hypothesis predicted a positive coefficient on *DR*, $\boldsymbol{\theta}_1 > 0$. The third hypothesis predicted a positive coefficient on *UDR*, $\boldsymbol{\theta}_2 > 0$. The estimation was performed with *DR* and *UDR* measured first in BOEs-energy and then in BOEs-revenue.

A seventh regression model was also estimated. This regression model tested hypothesis 1; however, proven reserves of gas and proven reserves of oil were entered as separate variables. Regression model 7 was estimated as follows:

$$P_{it} = \alpha_0 + \alpha_1 D1 + \alpha_2 D2 + \alpha_3 D3 + \delta_1 y_{it} + \delta_2 x_{it} + \delta_3 y_{it-1} + \theta_1 RO_{it} + \theta_2 RG_{it} + \epsilon_{it} \tag{26}$$

where

P_{it} = stock price per share for firm *i* at time *t*,

D1= a dummy variable; 1 if the year is 1990, 0 otherwise,

D2= a dummy variable; 1 if the year is 1991, 0 otherwise,

D3= a dummy variable; 1 if the year is 1992, 0 otherwise,

y_{it} = (net) book value per share for firm *i* at time *t*,

x_{it} = earnings per share for firm *i* at time *t*,

y_{it-1} = (net) book value per share for firm *i* at time *t* - 1,

RO_{it} = proven reserves of oil per share for firm *i* at time *t*,

RG_{it} = proven reserves of gas per share for firm *i* at time *t*,

ϵ_{it} = the error term.

The first hypothesis predicted positive coefficients on *RO* and *RG*, $\boldsymbol{\theta}_1 > 0$ and $\boldsymbol{\theta}_2 > 0$, respectively.

Regression model 8 was estimated as follows:

$$P_{it} = \alpha_0 + \alpha_1 D1 + \alpha_2 D2 + \alpha_3 D3 + \delta_1 y_{it} + \delta_2 x_{it} + \delta_3 y_{it-1} + \theta_1 DRO_{it} + \theta_2 UDRO_{it} + \theta_3 DRG_{it} + \theta_4 UDRG_{it} + \epsilon_{it} \tag{27}$$

where

P_{it} = stock price per share for firm i at time t,

$D1$= a dummy variable; 1 if the year is 1990, 0 otherwise,

$D2$= a dummy variable; 1 if the year is 1991, 0 otherwise,

$D3$= a dummy variable; 1 if the year is 1992, 0 otherwise,

y_{it} = (net) book value per share for firm i at time t,

x_{it} = earnings per share for firm i at time t,

y_{it-1} = (net) book value per share for firm i at time t - 1,

DRO_{it} = proven developed reserves of oil per share for firm i at time t,

$UDRO_{it}$ = proven undeveloped reserves of oil per share for firm i at time t,

DRG_{it} = proven developed reserves of gas per share for firm i at time t,

$UDRG_{it}$ = proven undeveloped reserves of gas per share for firm i at time t,

ϵ_{it} = the error term.

This regression model was used to test hypotheses 2 and 3. Similar to regression model 7, proven reserves of gas and proven reserves of oil were entered as separate variables. The second hypothesis predicted the coefficients on *DRO* and *DRG* to be positive, $\theta_1 > 0$ and $\theta_3 > 0$, respectively. The third hypothesis predicted the coefficients on *UDRO* and *UDRG* to be positive, $\theta_2 > 0$ and $\theta_4 > 0$, respectively.

Hypotheses 4 and 5 were tested using the ninth regression model. This regression model was estimated as follows:

$$P_{it} = \alpha_0 + \alpha_1 D1 + \alpha_2 D2 + \alpha_3 D3 + \delta_1 y_{it} + \delta_2 x_{it} + \delta_3 y_{it-1} + \theta_5 E_{it} + \theta_6 E*A_{it} + \epsilon_{it} \quad \textbf{(28)}$$

where

P_{it} = stock price per share for firm i at time t,

$D1$= a dummy variable; 1 if the year is 1990, 0 otherwise,

$D2$= a dummy variable; 1 if the year is 1991, 0 otherwise,

$D3$= a dummy variable; 1 if the year is 1992, 0 otherwise,

y_{it} = (net) book value per share for firm i at time t,

x_{it} = earnings per share for firm i at time t,

y_{it-1} = (net) book value per share for firm i at time t - 1,

E_{it} = the effort exerted by firm i for the period t - 1 to t,

A_{it} = the ability of firm i at time t to discover or extend proven reserves,

ϵ_{it} = the error term.

The fourth hypothesis predicted the coefficient on E to be positive, $\theta_5 > 0$. Hypothesis 5 predicted a positive value for the coefficient on $E*A$, $\theta_6 > 0$. Again, regression model 9 was first estimated with A measured in BOEs-energy and then with A measured in BOEs-revenue.

A disadvantage of testing hypotheses 1, 2, and 3 in separate regression models from hypotheses 4 and 5 was that conclusion could not be drawn about the value-relevance of information relating to proven reserves in place at time t verses information relating to the future discovery and extensions of proven reserves. Magliolo (1986) suggested that the market anticipated the discovery of new reserves. Therefore, information about the future discovery and extension of proven reserves was important, not information about the proven reserves in place at time *t*. To address this problem Davidson and MacKinnon's *J* Test for nonnested models was performed. This tested H_0, that information concerning proven reserves in place at time *t* was the correct model against H_1, that information concerning the future discovery and extensions of proven reserves was the correct model and vice versa. Regression models 5, 6, 7, and 8 were used as the model for H_0. They were test against H_1 which was regression model 9. Unfortunately, in testing H_0 verses H_1 and vice versa, all possibilities (reject both, reject neither, or reject either one of the two hypotheses) could occur (Greene, 1990; p. 232). The implication was that conclusions were only drawn when one of the two hypothesis was rejected.

4.2 Sample Selection

All the data used for estimating the regression models was taken from the Arthur Andersen Oil & Gas Reserve Disclosure database. This proprietary database was prepared as part of an ongoing research program on the oil and gas industry by Arthur Andersen Co. The companies included in the database accounted for nearly 60 percent of the total proven oil and gas reserves and of the total oil and gas production in the U.S. (Arthur Andersen, 1994). Reserve quantity, value, cost and other financial data were included in the database for 246 public companies for the five years 1989 to 1993.

The following sampling criteria were used to select observations for the estimation of the regression models. First, to avoid measurement error that would result from exchange rate translations, sample companies had to report financial results in U.S. dollars. Second, sample companies had to have a December 31 year-end to ensure uniform disclosure of accounting and reserve data. Third, firms that failed to report sufficient data to calculate the dependent and independent variables were omitted. Because the theoretical valuation model represented in equation (13) includes the prior year's book value as one of the independent variables, the sample included observations for the period 1990 to 1993.

Table 1 reports the number of observations included in the sample by year, by reporting method (i.e., FC or SE) and in total. The number of yearly observations ranged from a low of 94 in 1990 to a high of 103 in 1991, with the total firm-year observations for the four periods being 399. Of the total firms, approximately 55 percent reported using the SE methods and approximately 45 percent reported using the FC method.

Table 1
Number of Firms in Sample

Year	Full Cost	Successful Efforts	Total
1990	40	54	94
1991	46	57	103
1992	45	55	100
1993	48	54	102
Total	179	220	399

Table 2A presents descriptive statistics for the pooled sample (both FC and SE firms). Descriptive statistics for FC firms and SE firms are presented in Table 2B and Table 2C, respectively. Each table presents the mean, median, standard deviation, skewness, kurtosis, maximum value, and minimum value for the dependent variable stock price (P_t) and for each independent variable. All variables are expressed on a per share basis.

On average the observations of SE firms are larger than FC firms. Stock price (P_t), book value per share (y_t), and earnings per share (x_t) are all larger for SE firms. SE firms also have more proven reserves per share as well as having a higher effort per share (E), as measured by exploratory costs per share, than FC firms. These results are consistent with that of prior studies (for example; Bandyopadhyay, 1994; Malmquist, 1990; and Harrison and Ohlson, 1987) which found SE firms to be larger. This difference is also consistent with SE adopters being large vertically integrated firms and FC adopters being smaller independent firms.

Table 2A
Descriptive Statistics
Pooled Sample (399)

Variable	Mean	Median	Standard Deviation	Skewness	Kurtosis	Maximum	Minimum
P_t	15.90	9.13	17.40	1.55	2.07	0.02	87.13
y_t	10.46	6.83	11.79	2.25	7.35	79.15	-4.65
x	0.25	0.21	2.85	-7.79	102.09	8.11	-39.90
y_{t-1}	10.63	6.07	12.48	2.20	6.58	79.15	-8.84
RO	1.19	0.61	1.55	2.36	6.04	7.96	0.00
RG	11.34	6.38	14.32	2.95	12.72	99.75	0.00
DRO	0.88	0.45	1.17	2.49	6.93	6.51	0.00
DRG	8.97	4.61	10.84	2.23	6.60	68.04	0.00
UDRO	0.31	0.09	0.52	3.00	10.78	3.23	0.00
UDRG	2.37	0.92	4.40	5.11	36.89	45.80	0.00
E	0.52	0.26	0.71	2.59	8.84	4.65	0.00
R^E	3.09	1.93	3.32	2.04	4.48	17.88	0.03
R^R	2.46	1.41	3.41	5.79	58.86	44.50	0.02
DR^E	2.37	1.52	2.55	1.80	3.04	12.20	0.03
DR^R	1.87	1.09	2.54	5.42	53.78	32.49	0.02
UDR^E	0.70	0.34	0.99	2.77	10.71	7.78	0.00
UDR^R	0.59	0.25	1.01	5.28	45.42	12.00	0.00
$E*A^E$	0.22	0.10	0.37	7.10	85.45	5.29	0.00
$E*A^R$	0.17	0.08	0.35	8.06	88.33	4.43	0.00

The superscripts ^{E} and ^{R} represent BOEs-Energy and BOEs-Revenue, respectively.

Table 2B
Descriptive Statistics
Full Cost Sample (179)

Variable	Mean	Median	Standard Deviation	Skewness	Kurtosis	Maximum	Minimum
P_t	12.03	7.63	11.90	1.40	1.37	49.75	0.16
y_t	8.04	5.26	7.20	1.20	0.87	34.82	-0.56
x	0.17	0.18	1.66	-3.57	28.83	4.78	-13.74
y_{t-1}	7.73	5.03	7.17	1.42	1.90	35.50	-0.59
RO	0.61	0.39	0.62	1.92	4.18	3.36	0.00
RG	7.88	5.14	7.74	1.64	2.92	36.47	0.00
DRO	0.45	0.28	0.46	2.16	5.73	2.65	0.00
DRG	6.51	3.80	6.87	1.70	3.02	31.21	0.00
UDRO	0.16	0.06	0.23	2.25	5.12	1.25	0.00
UDRG	1.37	0.74	1.78	2.48	7.00	9.58	0.00
E	0.36	0.16	0.46	2.25	6.64	2.84	0.00
R^E	1.92	1.55	1.54	1.15	0.88	6.66	0.01
R^R	1.37	1.07	1.11	1.21	1.05	5.14	0.01
DR^E	1.53	1.07	1.35	1.42	1.90	6.41	0.01
DR^R	1.07	0.78	0.93	1.41	1.85	4.57	0.01
UDR^E	0.38	0.24	0.42	1.84	3.75	2.26	0.00
UDR^R	0.30	0.17	0.33	1.82	3.42	1.74	0.00
$E*A^E$	0.17	0.09	0.24	2.87	10.42	1.55	0.00
$E*A^R$	0.12	0.06	0.18	2.78	9.28	1.05	0.00

The superscripts ^{E} and ^{R} represent BOEs-Energy and BOEs-Revenue, respectively.

Table 2C
Descriptive Statistics
Successful Efforts Sample (220)

Variable	Mean	Median	Standard Deviation	Skewness	Kurtosis	Maximum	Minimum
P_t	19.05	11.69	20.32	1.24	0.76	87.13	0.13
y_t	12.43	7.68	14.21	1.90	4.65	79.15	-4.65
x	0.32	0.27	3.54	-7.18	77.83	8.11	-39.9
y_{t-1}	12.99	6.78	15.13	1.76	3.72	79.15	-8.84
RO	1.67	0.90	1.88	1.67	2.45	7.96	0.01
RG	14.15	7.56	17.50	2.45	8.05	99.76	0.00
DRO	1.23	0.69	1.42	1.78	3.02	6.51	0.01
DRG	10.97	6.24	12.90	1.88	4.17	68.03	0.00
UDRO	0.43	0.14	0.63	2.32	5.79	3.23	0.00
UDRG	3.18	1.10	5.59	4.11	22.71	45.80	0.00
E	0.64	0.40	0.84	2.22	5.94	4.65	0.00
R^E	4.02	2.70	4.01	1.45	1.61	17.88	0.03
R^R	3.35	1.98	4.30	4.72	38.31	44.50	0.02
DR^E	3.06	1.94	3.05	1.29	0.81	12.20	0.02
DR^R	2.52	1.50	3.18	4.49	35.78	32.49	0.01
UDR^E	0.96	0.47	1.22	2.09	5.74	7.78	0.00
UDR^R	0.83	0.38	1.27	4.20	28.22	12.00	0.00
$E*A^E$	0.26	0.12	0.44	6.96	72.68	5.29	0.00
$E*A^R$	0.21	0.10	0.43	7.08	62.17	4.43	0.00

The superscripts ^{E} and ^{R} represent BOEs-Energy and BOEs-Revenue, respectively.

CHAPTER V

RESULTS OF THE STUDY

This chapter is organized as follows. First, the results of each regression model estimated are discussed. This is followed a discussion of the results from Davidson and MacKinnon's *J* Test. Finally, the chapter concludes with a summary of the results.

5.1 Results of Regression Models

The results from estimating the regression models are reported in the tables that follow. Each table reports the results of the estimations performed using the pooled sample (both FC and SE firms), only full cost (FC) firms, and only successful efforts (SE) firms. Coefficients and their respective test statistic are reported. Also reported are the adjusted R^2 and White's chi-square, the test derived by White (1980) to test the null of homoscedasticity and model specification. For estimations where the null of homoscedasticity is rejected White's *t*-statistic is reported as the test statistic. In cases where the null of homoscedasticity is not reject the *t*-statistic is reported.

5.1.1 Regression Model 1

The results of regression model 1, which tests hypotheses 1, 4, and 5, are reported in Tables 3A and 3B. The results in Table 3A are for the estimations with variables measured in BOEs-energy. Table 3B reports results for estimations with variables measured in BOEs-revenue. The pooled sample supports only the fourth hypothesis.

Effort (*E*) is significant at the p>.1 level for BOEs-energy (Table 3A) and at the p>.05 level for BOEs-revenue (Table 3B). Control variables earnings per share at time *t* (x_t) and book value per share at time *t-1* (y_{t-1}) are also significant.

FC firm estimations of the first regression model support hypotheses four and five. Both *E* and the interaction term effort times ability (*E**A*) are significant at the p>.01 level. Control variables y_t (book value per share at time *t*), x_t, and y_{t-1} are also significant. SE firm estimation indicate that there is support for the first and the fourth hypotheses. In support of the first hypothesis, *R* is significant at the p>.1 level when measured in BOEs-energy (Table 3A). In support of the fourth hypothesis, *E* is significant at the p>.01 level for BOEs-energy (Table 3A) and at the p>.05 level for BOEs-revenue (Table 3B). Similar to the results for the pooled sample, control variables x_t and y_{t-1} are significant.

Table 3A
Results for Regression Model 1
BOEs - Energy

$$P_{it} = \alpha_0 + \alpha_1 D1 + \alpha_2 D2 + \alpha_3 D3 + \delta_1 y_{it} + \delta_2 x_{it} + \delta_3 y_{it-1} + \theta_1 R_{it} + \theta_5 E_{it} + \theta_6 E*A_{it} + \epsilon_{it}$$

Variable	Predicted Sign	Pooled (White's t-stat)	Full Cost (t-stat)	Successful Efforts (White's t-stat)
Intercept		4.2659 (3.945)***	0.1273 (0.141)	6.1143 (3.790)***
D1		-1.7067 (-1.368)	-0.4512 (-0.414)	-3.2608 (-1.628)*
D2		-2.5666 (-2.058)**	-1.2668 (-1.199)	-4.0399 (-1.953)**
D3		-0.4738 (-0.402)	-0.2594 (-0.247)	-0.7032 (-0.353)
y_t		0.1300 (0.513)	0.3428 (1.825)*	-0.0618 (-0.164)
x_t		2.2353 (6.076)***	2.2232 (7.854)***	2.3918 (4.719)***
y_{t-1}		0.7446 (3.174)***	0.8620 (4.791)***	0.8240 (2.440)**
R	+	0.4716 (1.195)	0.2207 (0.660)	0.6390 (1.297)*
E	+	2.5730 (1.494)*	3.7971 (3.766)***	2.9655 (1.459)*
E*A	+	0.3773 (0.110)	4.6831 (3.252)***	-0.9120 (-0.249)
Adj R^2		0.7314	0.8212	0.7079
White's chi-square		79.43***	56.78	77.70***

Significance levels (one-tailed for variables used to test the hypotheses and two-tailed for all other variables): * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

Table 3B
Results for Regression Model 1
BOEs - Revenue

$$P_{it} = \alpha_0 + \alpha_1 D1 + \alpha_2 D2 + \alpha_3 D3 + \delta_1 y_{it} + \delta_2 x_{it} + \delta_3 y_{it-1} + \theta_1 R_{it} + \theta_5 E_{it} + \theta_6 E{*}A_{it} + \epsilon_{it}$$

Variable	Predicted Sign	Pooled (White's t-stat)	Full Cost (t-stat)	Successful Efforts (White's t-stat)
Intercept		4.8010 (4.284)***	0.0418 (0.054)	6.8187 (4.105)
D1		-1.8113 (-1.415)	-0.1870 (-0.165)	-3.2816 (-1.612)
D2		-2.7424 (-2.225)**	-1.0913 (-1.084)	-4.1910 (-2.051)**
D3		-0.4032 (-0.340)	-0.0988 (-0.097)	-0.5326 (-0.267)
y_t		0.1721 (0.6814)	0.3340 (2.007)**	-0.0204 (-0.052)
x_t		2.2385 (5.955)***	2.2255 (6.445)***	2.3866 (4.669)***
y_{t-1}		0.7591 (3.266)***	0.8800 (5.163)***	0.8317 (2.470)**
R	+	0.1157 (0.250)	0.2165 (0.460)	0.3211 (0.582)
E	+	3.3845 (1.920)**	3.8842 (3.291)***	3.6024 (1.742)**
E*A	+	-0.8063 (-0.277)	6.2453 (3.096)***	-2.193 (-0.733)
Adj R^2		0.7270	0.8195	0.7023
White's chi-square		81.48***	57.02	79.22***

Significance levels (one-tailed for variables used to test the hypotheses and two-tailed for all other variables): * p<0.1, ** p<0.05, *** p<0.01.

5.1.2 Regression Model 2

The second regression model tests the second, third, fourth, and fifth hypotheses. The results of these estimations are reported in Tables 4A and 4B. The results in Table 4A are for the estimations with variables measured in BOEs-energy. Table 4B reports results for estimations with variables measured in BOEs-revenue. The results for the pooled sample support both the second and fourth hypotheses. Proven developed reserves (*DR*) is significant at the $p<.01$ level when measured in BOEs-energy (Table 4A) and at the $p<.1$ level when measured in BOEs-revenue (Table 4B) to support the second hypothesis. In support of the fourth hypothesis, *E* is significant at the $p<.1$ level (Table 4A) and the $p<.05$ level (Table 4B). Again, control variables x_t and y_{t-1} are significant for estimations performed using the pooled sample.

When the second regression model is estimated using only FC firms the results support the fourth and fifth hypotheses. *E* and *E*A* are significant at the $p<.01$ level for both estimations (BOEs-energy and BOEs-revenue). Control variables y_t, x_t, and y_{t-1} are also significant. Estimations using only SE firms support the second and fourth hypotheses. In support of the second hypothesis *DR* is significant at the $p<.01$ level (BOEs-energy) and the $p<.05$ level (BOEs-revenue). *E* is significant at the $p<.1$ level for both estimations to support the fourth hypothesis. Control variables x_t and y_{t-1} are significant for the estimations performed using only SE firms.

Table 4A
Results for Regression Model 2
BOEs - Energy

$$P_{it} = \alpha_0 + \alpha_1 D1 + \alpha_2 D2 + \alpha_3 D3 + \delta_1 y_{it} + \delta_2 x_{it} + \delta_3 y_{it-1} + \theta_1 DR_{it} + \theta_2 UDR_{it} + \theta_5 E_{it} + \theta_6 E*A_{it} + \epsilon_{it}$$

Variable	Predicted Sign	Pooled (White's t-stat)	Full Cost (t-stat)	Successful Efforts (White's t-stat)
Intercept		4.0662 (3.980)***	0.2986 (0.327)	5.8890 (3.822)***
D1		-1.7615 (-1.428)	-0.5069 (-0.464)	-3.3262 (-1.671)*
D2		-2.4035 (-1.985)**	-1.2389 (-1.173)	-3.7612 (-1.864)*
D3		-0.3845 (-0.333)	-0.11894 (-0.180)	-0.6378 (-0.327)
y_t		0.1492 (0.590)	0.3846 (2.002)**	-0.0496 (-0.132)
x_t		2.2054 (5.980)***	2.1808 (7.627)***	2.3673 (4.672)***
y_{t-1}		0.7250 (3.052)***	0.8135 (4.376)***	0.7975 (2.372)**
DR	+	1.1194 (2.556)***	0.3499 (0.980)	1.3186 (2.536)***
UDR	+	-1.5567 (-1.673)	-0.9524 (-0.807)	-1.3683 (-1.188)
E	+	2.3098 (1.375)*	3.6960 (3.649)***	2.7142 (1.347)*
E*A	+	1.7098 (0.5659)	5.5769 (2.662)***	0.4972 (0.1493)
Adj R^2		0.7372	0.8213	0.7134
White's chi-square		92.48***	70.02	89.36***

Significance levels (one-tailed for variables used to test the hypotheses and two-tailed for all other variables): *p<0.1, ** p<0.05, *** p<0.01.

Table 4B
Results for Regression Model 2
BOEs - Revenue

$$P_{it} = \alpha_0 + \alpha_1 D1 + \alpha_2 D2 + \alpha_3 D3 + \delta_1 y_{it} + \delta_2 x_{it} + \delta_3 y_{it-1} + \theta_1 DR_{it} + \theta_2 UDR_{it} + \theta_5 E_{it} + \theta_6 E*A_{it} + \epsilon_{it}$$

Variable	Predicted Sign	Pooled (White's t-stat)	Full Cost (t-stat)	Successful Efforts (White's t-stat)
Intercept		4.6143 (4.215)***	0.1592 (0.169)	6.6204 (4.070)***
D1		-1.7021 (-1.332)	-0.1935 (-0.173)	-3.1877 (-1.568)
D2		-2.4682 (-2.066)**	-1.0486 (-0.981)	-3.8108 (-1.917)*
D3		-0.27911 (-0.239)	-0.0387 (-0.036)	-0.3988 (-0.203)
y_t		0.1743 (0.693)	0.3588 (1.88)*	-0.0241 (-0.062)
x_t		2.2112 (5.909)***	2.1948 (7.677)***	2.3650 (4.651)***
y_{t-1}		0.7395 (3.174)***	0.8442 (4.556)***	0.8174 (2.430)**
DR	+	0.9763 (1.584)*	0.4943 (0.933)	1.1768 (1.729)**
UDR	+	-2.2504 (-2.414)	-1.1948 (-0.824)	-1.9968 (-1.823)
E	+	3.0258 (1.710)**	3.7342 (3.644)***	3.2661 (1.567)*
E*A	+	0.4757 (0.185)	7.1504 (2.585)***	-0.9253 (-0.342)
Adj R^2		0.7321	0.8195	0.7073
White's chi-square		89.64***	65.60	75.11*

Significance levels (one-tailed for variables used to test the hypotheses and two-tailed for all other variables): * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

5.1.3 Regression Model 3

Table 5 reports the results of estimations performed using the third regression model. Similar to regression model 1, regression model 3 tests hypotheses 1, 4, and 5. However, proven reserves of oil (*RO*) and proven reserves of gas (*RG*) are not combined when testing the first hypothesis. The results of the estimation perform using the pooled sample supports the first hypothesis. *RO* is significant at the $p<.01$ level. Once again, control variables x_t and y_{t-1} are significant.

The results of the estimations performed with only FC firms supports all three hypotheses. In support of hypothesis 1, *RG* is significant at the $p<.1$ level. *E* is significant at the $p<.01$ level and $E*A$ is significant at the $p<.05$ level to support the fourth and fifth hypotheses, respectively. Control variables y_t, x_t, and y_{t-1} are also significant for the estimation performed using only FC firms. With *RO* significant at the $p<.01$ level, the estimation performed using only SE firms supports only the first hypothesis. Control variables x_t and y_{t-1} are significant for this estimation.

Table 5
Results for Regression Model 3

$$P_{it} = \alpha_0 + \alpha_1 D1 + \alpha_2 D2 + \alpha_3 D3 + \delta_1 y_{it} + \delta_2 x_{it} + \delta_3 y_{it-1} + \theta_1 RO_{it} + \theta_2 RG_{it} + \theta_5 E_{it} + \theta_6 E{*}A_{it} + \epsilon_{it}$$

Variable	Predicted Sign	Pooled (White's t-stat)	Full Cost (t-stat)	Successful Efforts (White's t-stat)
Intercept		4.0426 (3.988)***	0.4925 (0.535)	5.4225 (3.646)***
D1		-1.5017 (-1.193)	-0.6379 (-0.585)	-3.0093 (-1.504)
D2		-2.4654 (-2.054)**	-1.3225 (-1.258)	-3.7839 (-1.972)**
D3		-0.5758 (-0.502)	-0.2430 (-0.232)	-0.9827 (-0.521)
y_t		0.1321 (0.552)	0.3600 (1.923)*	-0.0751 (-0.218)
x_t		2.1105 (5.822)***	2.2131 (7.857)***	2.1820 (4.520)***
y_{t-1}		0.7658 (3.430)***	0.8216 (4.547)***	0.8551 (2.783)***
RO	+	1.7100 (2.886)***	-0.6992 (-1.077)	2.6206 (3.567)***
RG	+	-0.0232 (-0.384)	0.0975 (1.464)*	-0.0369 (-0.600)
E	+	1.4531 (0.426)	3.9069 (3.886)***	0.7828 (0.358)
E*A	+	1.8532 (0.583)	4.1121 (2.129)**	1.4163 (0.430)
Adj R^2		0.7410	0.8230	0.7332
White's chi-square		97.57***	59.12	76.21*

Significance levels (one-tailed for variables used to test the hypotheses and two-tailed for all other variables): *p<0.1, ** p<0.05, *** p<0.01.

5.1.4 Regression Model 4

Table 6 reports the results of the estimations performed using regression model 4. Similar to regression model 2, regression model 4 tests hypotheses 2, 3, 4, and 5. However, proven reserves of oil and proven reserves of gas are not combine when testing the second and third hypotheses. The results of the estimation performed using the pooled sample support the second and fifth hypotheses. In support of the second hypothesis proven developed reserves of oil (*DRO*) and proven developed reserves of gas (*DRG*) are significant at the $p<.01$ and the $p<.05$ level, respectively. In support of the fifth hypothesis, *E*A* is at the $p<.05$ level. Control variables x_t and y_{t-1} are again significant for the estimation performed with the pooled sample.

The FC firm estimation supports the second, fourth, and fifth hypotheses. In support of the second hypothesis, *DRG* is significant at the $p<.05$ level. In support of the fourth and fifth hypotheses, *E* and *E*A* are both significant at the $p<.01$ level. Again the three control variables, y_t, x_t, and y_{t-1}, are significant for the estimation performed using with only FC firms. The SE firm estimation results support the second and fifth hypotheses. In support of hypothesis 2, *DRO* and *DRG* are significant at the $p<.01$ and the $p<.1$ levels, respectively. In support of the fifth hypothesis, *E*A* is significant at the $p<.1$ level. Control variables x_t and y_{t-1} are once again significant for the SE firm estimation.

Table 6
Results for Regression Model 4

$$P_{it} = \alpha_0 + \alpha_1 D1 + \alpha_2 D2 + \alpha_3 D3 + \delta_1 y_{it} + \delta_2 x_{it} + \delta_3 y_{it-1} + \theta_1 DRO_{it} + \theta_2 UDRO_{it} + \theta_3 DRG_{it} + \theta_4 UDRG_{it} + \theta_5 E_{it} + \theta_6 E*A_{it} + \epsilon_{it}$$

Variable	Predicted Sign	Pooled (White's t-stat)	Full Cost (t-stat)	Successful Efforts (t-stat)
Intercept		3.6065 (3.832)***	0.6411 (0.689)	5.0537 (3.130)***
D1		-1.6097 (-1.305)	-0.8377 (-0.759)	-3.0968 (-1.511)
D2		-2.280 (-1.978)**	-1.4397 (-1.358)	-3.4401 (-1.722)*
D3		-0.4876 (-0.439)	-0.2293 (-0.219)	-0.9239 (-0.460)
y_t		0.1608 (0.673)	0.4171 (2.150)**	-0.0595 (-0.242)
x_t		2.0425 (5.545)***	2.1521 (7.499)***	2.1412 (6.439)***
y_{t-1}		0.7303 (3.266)***	0.7778 (4.172)***	0.8234 (3.834)***
DRO	+	1.9197 (2.548)***	-1.5244 (-1.365)	3.0828 (3.853)***
UDRO	+	0.9512 (1.056)	0.8953 (0.418)	1.1194 (0.789)
DRG	+	0.1597 (1.907)**	0.1399 (1.877)**	0.1246 (1.301)*
UDRG	+	-0.6303 (-3.081)	-0.2682 (-0.859)	-0.5179 (-2.258)
E	+	1.0671 (0.597)	3.8595 (3.804)***	0.5054 (0.360)
E*A	+	4.2873 (1.855)**	5.1152 (2.293)***	3.4795 (1.594)*
Adj R2		0.7504	0.8226	0.7395
White's chi-square		112.14**	91.05	94.36

Significance levels (one-tailed for variables used to test the hypotheses and two-tailed for all other variables): *p<0.1, ** p<0.05, *** p<0.01.

5.1.5 Regression Model 5

The fifth regression model tests only the first hypothesis. The results in Table 7A are for estimations performed with proven reserves (*R*) measured in BOEs-energy. Table 7B reports results for estimations performed with *R* measured in BOEs-revenue. *R* is significant, and therefore supports the first hypothesis, for all estimation performed with *R* measured in BOEs-energy (Table 7A). The estimations performed using the pooled sample and using only FC firms are significant at the $p<.01$ level. The estimation performed using only SE firms is significant at the $p<.05$ level. For estimations performed with *R* measured in BOEs-revenue (Table 7B) only the FC firm estimation supports hypothesis 1. *R* is significant at the $p<.01$ level. Again, control variables x_t and y_{t-1} are significant for the estimations performed using the pooled sample and using only SE firms. The three control variables y_t, x_t, and y_{t-1} are significant for the estimation performed using only FC firms. The significance of control variables is the same whether *R* is measured in BOEs-energy or BOEs-revenue.

Table 7A
Results for Regression Model 5
BOEs - Energy

$$P_{it} = \alpha_0 + \alpha_1 D1 + \alpha_2 D2 + \alpha_3 D3 + \delta_1 y_{it} + \delta_2 x_{it} + \delta_3 y_{it-1} + \theta_1 R_{it} + \epsilon_{it}$$

Variable	Predicted Sign	Pooled (White's t-stat)	Full Cost (White's t-stat)	Successful Efforts (White's t-stat)
Intercept		4.1469 (3.889)***	0.2033 (0.257)	5.8109 (3.487)***
D1		-1.1328 (-0.910)	-0.0352 (-0.030)	-2.4759 (1.224)
D2		-2.3126 (-1.796)*	-1.5592 (-1.431)	-3.3998 (-1.572)
D3		-0.6095 (-0.509)	-0.7352 (-0.703)	-0.7195 (-0.357)
y_t		0.1907 (0.767)	0.3592 (1.707)*	0.0424 (0.117)
x_t		2.0970 (6.037)***	2.0236 (5.972)***	2.2233 (4.650)***
y_{t-1}		0.7679 (3.275)***	0.9136 (4.584)***	0.8185 (2.504)**
R	+	0.6746 (2.092)***	1.1054 (3.065)***	0.7534 (1.818)**
Adj R^2		0.7274	0.8004	0.7044
White's chi-square		67.79***	57.37***	50.06***

Significance levels (one-tailed for variables used to test the hypotheses and two-tailed for all other variables): * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

Table 7B
Results for Regression Model 5
BOEs - Revenue

$$P_{it} = \alpha_0 + \alpha_1 D1 + \alpha_2 D2 + \alpha_3 D3 + \delta_1 y_{it} + \delta_2 x_{it} + \delta_3 y_{it-1} + \theta_1 R_{it} + \epsilon_{it}$$

Variable	Predicted Sign	Pooled (White's t-stat)	Full Cost (White's t-stat)	Successful Efforts (White's t-stat)
Intercept		4.7505 (4.145)***	0.0240 (0.030)	6.6696 (3.787)***
D1		-1.1177 (-0.876)	0.4260 (0.358)	-2.4607 (-1.188)
D2		-2.3143 (-1.780)*	-1.2013 (-1.124)	-3.3594 (-1.542)
D3		-0.4847 (-0.401)	-0.6012 (-0.570)	-0.4782 (-0.236)
y_t		0.2333 (0.921)	0.3616 (1.731)*	0.0869 (0.228)
x_t		2.0629 (5.19)***	1.9970 (6.004)***	2.1839 (4.484)***
y_{t-1}		0.7957 (3.420)***	0.9299 (4.705)***	0.3534 (2.569)***
R	+	0.2869 (0.451)	1.4064 (2.915)***	0.3534 (0.8101)
Adj R^2		0.7194	0.7977	0.6950
White's chi-square		67.32***	50.27***	49.23**

Significance levels (one-tailed for variables used to test the hypotheses and two-tailed for all other variables): * p<0.1, ** p<0.05, *** p<0.01.

5.1.6 Regression Model 6

The results for regression model 6, which tests the second and third hypotheses, are reported in Tables 8A and 8B. The results in table 9A are for estimations performed with proven reserves variables *DR* and *UDR* measured in BOEs-energy. Table 8B reports the results of estimations performed with *DR* and *UDR* measured in BOEs-revenue. *DR* is significant at the p<.01 level for all estimations performed using regression model 6. *UDR* is not significant for any estimation. This holds whether *DR* and *UDR* are measured in BOEs-energy (Table 8A) or BOEs-revenue (Table 8B). Thus there is support for the second hypothesis and not for the third hypothesis. Control variables x_t and y_{t-1} are significant for the estimations performed using the pooled sample and for the estimations performed using only SE firms. For the estimations performed using only FC firms the control variables y_t, x_t, and y_{t-1} are significant.

Table 8A
Results for Regression Model 6
BOEs - Energy

$$P_{it} = \alpha_0 + \alpha_1 D1 + \alpha_2 D2 + \alpha_3 D3 + \delta_1 y_{it} + \delta_2 x_{it} + \delta_3 y_{it-1} + \theta_1 DR_{it} + \theta_2 UDR_{it} + \epsilon_{it}$$

Variable	Predicted Sign	Pooled (White's t-stat)	Full Cost (White's t-stat)	Successful Efforts (White's t-stat)
Intercept		4.0104 (4.022)***	0.2260 (0.282)	5.6021 (3.534)***
D1		-1.1438 (-0.889)	-0.0450 (-0.038)	-2.4139 (-1.222)
D2		-2.2218 (-1.763)*	-1.5604 (-1.429)	-3.1879 (-1.513)
D3		-0.5650 (-0.444)	-0.7307 (-0.702)	-0.6982 (-0.351)
y_t		0.2032 (1.165)	0.3650 (1.703)*	0.0421 (0.118)
x_t		2.0702 (8.732)***	2.0186 (5.964)***	2.2016 (4.588)***
y_{t-1}		0.7404 (4.708)***	0.9068 (4.363)***	0.7985 (2.446)**
DR	+	1.3317 (4.702)***	1.1315 (2.395)***	1.4887 (3.250)***
UDR	+	-1.1592 (-1.808)	0.9627 (1.092)	-1.1704 (-0.974)
Adj R^2		0.7327	0.7992	0.7103
White's chi-square		73.21***	66.76***	53.98**

Significance levels (one-tailed for variables used to test the hypotheses and two-tailed for all other variables): * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

Table 8B
Results for Regression Model 6
BOEs - Revenue

$$P_{it} = \alpha_0 + \alpha_1 D1 + \alpha_2 D2 + \alpha_3 D3 + \delta_1 y_{it} + \delta_2 x_{it} + \delta_3 y_{it-1} + \theta_1 DR_{it} + \theta_2 UDR_{it} + \epsilon_{it}$$

Variable	Predicted Sign	Pooled (White's t-stat)	Full Cost (White's t-stat)	Successful Efforts (White's t-stat)
Intercept		4.5603 (4.102)***	0.0986 (0.121)	6.4110 (3.743)***
D1		-0.9973 (-0.801)	0.4016 (0.338)	-2.2854 (-1.129)
D2		-2.0899 (-1.660)*	-1.1939 (-1.123)	-3.0160 (-1.430)
D3		-0.3889 (-0.326)	-0.5875 (-0.561)	-0.3636 (-0.182)
y_t		0.2304 (0.917)	0.3787 (1.76)*	0.0682 (0.179)
x_t		2.0460 (5.813)***	1.9818 (5.907)***	2.1765 (4.510)***
y_{t-1}		0.7683 (3.290)***	0.9056 (4.359)***	0.8316 (2.519)**
DR	+	1.2957 (2.570)***	1.6004 (2.262)***	1.4081 (2.429)***
UDR	+	-2.2231 (-2.335)	0.6248 (0.529)	-2.1988 (-2.060)
Adj R^2		0.7261	0.7969	0.7023
White's chi-square		68.41***	65.37***	51.32*

Significance levels (one-tailed for variables used to test the hypotheses and two-tailed for all other variables): * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

5.1.7 Regression Model 7

Table 9 reports the results for regression model 7. Similar to the fifth regression model, the seventh regression model test only hypothesis 1. However, proven reserves of oil (*RO*) and proven reserves of gas (*RG*) are entered as separate variables. The results of all three estimations support the first hypothesis. *RO* is significant at the $p<.01$ level for the estimations performed using the pooled sample and for the estimations performed using only SE firms. Control variables x_t and y_{t-1} are also significant for the estimations performed using the pooled sample and using only SE firms. *RG* is significant at the $p<.01$ level for the estimation performed using only FC firms. Also significant for the estimation performed using only FC firms are the control variables y_t, x_t, and y_{t-1}.

Table 9
Results for Regression Model 7

$$P_{it} = \alpha_0 + \alpha_1 D1 + \alpha_2 D2 + \alpha_3 D3 + \delta_1 y_{it} + \delta_2 x_{it} + \delta_3 y_{it-1} + \theta_1 RO_{it} + \theta_2 RG_{it} + \epsilon_{it}$$

Variable	Predicted Sign	Pooled (White's t-stat)	Full Cost (White's t-stat)	Successful Efforts (White's t-stat)
Intercept		4.0202 (3.985)***	0.6056 (0.7767)	5.3248 (3.451)***
D1		-1.0535 (-0.870)	-0.2220 (-0.186)	-2.5606 (-1.336)
D2		-2.3712 (-1.900)*	-1.5955 (-1.466)	-3.6295 (-1.789)*
D3		-0.7224 (-0.618)	-0.6948 (-0.668)	-1.0457 (-0.574)
y_t		0.1662 (0.709)	0.3748 (1.675)*	-0.0529 (-0.157)
x_t		2.0142 (5.965)***	2.0073 (5.896)***	2.1224 (4.701)***
y_{t-1}		0.7753 (3.486)***	0.8722 (4.098)***	0.8613 (2.815)***
RO	+	1.9597 (4.560)***	0.0406 (0.075)	2.7563 (4.988)***
RG	+	0.0083 (0.135)	0.2440 (3.493)***	-0.0178 (-0.296)
Adj R^2		0.7391	0.8028	0.7344
White's chi-square		79.75***	69.40***	70.17***

Significance levels (one-tailed for variables used to test the hypotheses and two-tailed for all other variables): * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

5.1.8 Regression Model 8

Table 10 reports the results of the estimations of regression model 8. Similar to regression model 6, regression model 8 tests the second and third hypotheses. However, proven reserves of oil and proven reserves of gas are not combined. The results of the estimation performed using the pooled sample support only the second hypothesis. *DRO* is significant at the $p<.01$ level and *DRG* is significant at the $<.05$ level. Control variables x_t and y_{t-1} are again significant for the estimations performed using the pooled sample.

The estimations performed using FC firms and using SE firms also support only the second hypothesis. However, only *DRG* is significant ($p<.01$) for the estimation performed using FC firms and only *DRO* is significant for the estimation performed using SE firms. The control variables y_t, x_t, and y_{t-1} are significant for the estimation performed using only FC firms and the control variables x_t and y_{t-1} are significant for the SE firm estimation.

Table 10
Results for Regression Model 8

$$P_{it} = \alpha_0 + \alpha_1 D1 + \alpha_2 D2 + \alpha_3 D3 + \delta_1 y_{it} + \delta_2 x_{it} + \delta_3 y_{it-1} + \theta_1 DRO_{it} + \theta_2 UDRO_{it} + \theta_3 DRG_{it} + \theta_4 UDRG_{it} + \epsilon_{it}$$

Variable	Predicted Sign	Pooled (White's t-stat)	Full Cost (White's t-stat)	Successful Efforts (White's t-stat)
Intercept		3.8004 (3.950)***	0.6264 (0.7950)	5.1362 (3.441)***
D1		-1.0659 (-0.901)	-0.3076 (-0.257)	-2.500 (-1.319)
D2		-2.2951 (-1.889)*	-1.6757 (-1.529)	-3.4286 (-1.731)*
D3		-0.6961 (-0.606)	-0.7257 (-0.697)	-1.0213 (-0.555)
y_t		0.1824 (0.780)	0.3829 (1.692)*	-0.0515 (-0.153)
x_t		1.9717 (5.731)***	1.9970 (6.030)***	2.1036 (4.628)***
y_{t-1}		0.7468 (3.338)***	0.8738 (4.001)***	0.8421 (2.739)***
DRO	+	2.3267 (4.165)***	-0.5625 (-0.580)	3.3943 (4.885)***
UDRO	+	0.8554 (0.952)	1.4139 (0.757)	0.9643 (0.860)
DRG	+	0.1565 (1.827)**	0.2603 (2.753)***	0.0994 (0.890)
UDRG	+	-0.4011 (-2.038)	0.1768 (0.757)	-0.3152 (-1.360)
Adj R^2		0.7450	0.8009	0.7381
White's chi-square		113.24***	83.81**	81.00**

Significance levels (one-tailed for variables used to test the hypotheses and two-tailed for all other variables): * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

5.1.9 Regression Model 9

The ninth regression model tests the fourth and fifth hypotheses. Tables 11A and 11B report the results for regression model 9. Table 11A reports the results for the estimations performed with the surrogate for ability (*A*) measured in BOEs-energy. The results for the estimations performed with the surrogate for *A* measured in BOEs-revenue are reported in Table 11B. The estimations performed using the pooled sample support only the fourth hypothesis. *E* is significant at the $p<.05$ level in both estimations (Tables 11A and 11B). Control variables x_t and y_{t-1} are also significant for both of the pooled sample estimations.

Both of the estimations of regression model 9 performed with only FC firms support hypotheses 4 and 5. *E* and *E*A* are significant at the $p<.01$ level in both cases. Again, the three control variables y_t, x_t, and y_{t-1} are significant for this estimation. With *E* significant at the $p<.05$ level, the estimations performed using only SE firms support the fourth hypothesis. Control variables x_t and y_{t-1} are also significant for the estimations performed using only SE firms.

Table 11A
Results for Regression Model 9
BOEs - Energy

$$P_{it} = \alpha_0 + \alpha_1 D1 + \alpha_2 D2 + \alpha_3 D3 + \delta_1 y_{it} + \delta_2 x_{it} + \delta_3 y_{it-1} + \theta_5 E_{it} + \theta_6 E*A_{it} + \epsilon_{it}$$

Variable	Predicted Sign	Pooled (White's t-stat)	Full Cost (White's t-stat)	Successful Efforts (White's t-stat)
Intercept		4.6680 (3.856)***	0.3092 (0.431)	7.0082 (3.850)
D1		-1.9362 (-1.563)	-0.4989 (-0.445)	-3.6463 (-1.811)*
D2		-2.6698 (-2082)**	-1.2519 (-1.249)	-4.2703 (-1.993)**
D3		-0.3336 (-0.286)	-0.2173 (-0.216)	-0.4486 (-0.229)
y_t		0.1785 (0.698)	0.3603 (2.205)**	0.0371 (-0.099)
x_t		2.2478 (6.105)***	2.2182 (6.381)***	2.3811 (4.670)***
y_{t-1}		0.7545 (3.174)***	0.8509 (5.016)***	0.8014 (2.374)**
E	+	3.1446 (2.063)**	4.0022 (3.382)***	3.6174 (1.942)**
E*A	+	1.6090 (0.505)	5.3187 (4.434)***	0.6959 (0.213)
Adj R^2		0.7284	0.8218	0.7021
White's chi-square		69.84***	49.13*	59.81**

Significance levels (one-tailed for variables used to test the hypotheses and two-tailed for all other variables): * p<0.1, ** p<0.05, *** p<0.01.

Table 11B
Results for Regression Model 9
BOEs - Revenue

$$P_{it} = \alpha_0 + \alpha_1 D1 + \alpha_2 D2 + \alpha_3 D3 + \delta_1 y_{it} + \delta_2 x_{it} + \delta_3 y_{it-1} + \theta_5 E_{it} + \theta_6 E*A_{it} + \epsilon_{it}$$

Variable	Predicted Sign	Pooled (White's t-stat)	Full Cost (White's t-stat)	Successful Efforts (White's t-stat)
Intercept		4.8510 (4.137)***	0.2065 (0.282)	7.0874 (3.964)***
D1		-1.8801 (-1.524)	-0.2743 (-0.244)	-3.140 (-1.753)*
D2		-2.7847 (-2.199)**	-1.1257 (-1.112)	-4.3682 (-2.061)**
D3		-0.3820 (-0.323)	-0.0768 (-0.076)	-0.4742 (-0.240)
y_t		0.1882 (0.739)	0.3466 (2.100)**	0.0493 (0.131)
x_t		2.2424 (6.013)***	2.2251 (6.446)***	2.3768 (4.628)***
y_{t-1}		0.7534 (3.184)***	0.8706 (5.110)***	0.7971 (2.370)**
E	+	3.5011 (2.301)**	4.0288 (3.366)***	3.8848 (2.078)**
E*A	+	-0.3047 (-0.112)	6.8462 (3.910)***	-0.7884 (-0.305)
Adj R^2		0.7275	0.8203	0.7021
White's chi-square		69.07***	50.80*	62.22***

Significance levels (one-tailed for variables used to test the hypotheses and two-tailed for all other variables): * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

5.2 Results of Davidson and MacKinnon's *J* Test

Davidson and Mackinnon's *J* Test for nonnested models tests H_0, that information concerning the proven reserves in place at time *t* is the correct model (the models used to test hypotheses 1, 2, 3) against H_1, the information concerning the future discovery and extension of proven reserves is the correct model (the model used to test hypotheses 4, 5) and visa versa. As stated in Chapter IV, conclusions can only be drawn when one of the two hypothesis is rejected.

Table 12 reports the results of the *J* Test. Because both hypotheses are rejected when using the pooled sample, no conclusion can be drawn about which is the correct model. However, the results of the tests performed using only FC firms clearly indicates that H_1 is the correct model. H_0 is rejected ($p<.01$) in favor of H_1 in every case whereas H_1 is never rejected in favor of H_0. The results of the tests performed using only SE firms are not as clear. However, when proven reserves of oil and proven reserves of gas are entered into H_0 as separate variables (regression models 7 and 8), H_1 is rejected ($p<.01$) in favor of H_0 while H_0 is not rejected in favor of H_1. McAleer, Fisher, and Volker (1982) indicate that overspecification guarantees consistency whereas underspecification does not. Therefore, it is preferable to include rather than exclude regressors. The implication is that conclusions should be drawn when H_0 is overspecified (more regressors) rather than under specified (less regressors). Based on this econometric evidence and the results of Davidson and Mackinnon's *J* Test it is concluded that H_0 is the correct model for SE firms.

Table 12
Results of Nonnested *J* Test

$$H_0: \; P_{it} = \alpha_0 + \alpha_1 D1 + \alpha_2 D2 + \alpha_3 D3 + \delta_1 y_{it} + \delta_2 x_{it} + \delta_3 y_{it-1} + \theta_n \boldsymbol{RES}_{it} + \epsilon_{it}$$

$$H_1: \; P_{it} = \alpha_0 + \alpha_1 D1 + \alpha_2 D2 + \alpha_3 D3 + \delta_1 y_{it} + \delta_2 x_{it} + \delta_3 y_{it-1} + \theta_5 E_{it} + \theta_6 E{*}A_{it} + \epsilon_{it}$$

Davidson and MacKinnon's *J* test was performed to test H_0 against H_1. *RES* represents the reserve variable(s) included in H_0. The column titled "Test H_1", tests whether H_1 should be rejected in favor of H_0. If the *t* ratio is significant then H_1 is rejected in favor of H_0. The column titled "Test H_0", tests whether H_0 should be rejected in favor of H_1. If the *t* ratio is significant then H_0 is rejected in favor of H_1.

Reserve Variables	Test H_1	Test H_0	Reject
Panel A: Pooled Sample			
R - BOEs-Energy	2.318**	2.752***	Both
R - BOEs-Revenue	0.530	3.579***	H_0
DR, UDR - BOEs-Energy	3.576***	2.918***	Both
DR, UDR - BOEs-Revenue	2.828***	3.258***	Both
RO, RG	4.528***	2.104**	Both
DRO, DRG, UDRO, UDRG	5.925***	2.439**	Both
Panel B: Full Cost Sample			
R - BOEs-Energy	0.510	4.694***	H_0
R - BOEs-Revenue	0.475	4.770***	H_0
DR, UDR - BOEs-Energy	0.701	4.803***	H_0
DR, UDR - BOEs-Revenue	0.656	4.835***	H_0
RO, RG	1.396	4.617***	H_0
DRO, DRG, UDRO, UDRG	1.521	4.764***	H_0
Panel C: Successful Efforts Sample			
R - BOEs-Energy	2.291**	2.014**	Both
R - BOEs-Revenue	1.086	2.618***	H_0
DR, UDR - BOEs-Energy	3.197***	2.072**	Both
DR, UDR - BOEs-Revenue	2.394**	2.367**	Both
RO, RG	5.157***	0.362	H_1
DRO, DRG, UDRO, UDRG	5.796***	0.922	H_1

Significance levels (two-tailed): * p<.01, ** p <0.05, *** p<0.01.

5.3 Summary of Results

In summary, the results of the study support all but the third hypothesis. The first hypothesis, the market value of the firm is positively related to proven reserves, is supported by the results of the study. However, the support depends on the conversion method used to combine proven reserves of oil and proven reserves of gas. When combined using an energy-based method (see Table 7A) the results of all of the estimations support the first hypothesis. Only the results of the estimation performed using FC firms support hypothesis 1 when a revenue-based conversion method is used (see Table 7B). Additionally, when proven reserves of oil and proven reserves of gas are entered as separate variables, proven reserves of gas is significant for FC firms and proven reserves of oil is significant for SE firms (see Table 9).

The second hypothesis, the market value of the firm is positively related to proven developed reserves, is also supported by the results of the study. Proven developed reserves is significant whether an energy-based or a revenue-based conversion method is used. However, when proven developed reserves of oil and proven developed reserves of gas are entered as separate variables the results are not consistent across reporting methods. Proven developed reserves of gas is significant for FC firms and proven developed reserves of oil is significant for SE firms (see Table 10). The third hypothesis, the market value of the firm is positively related to proven undeveloped reserves, is not supported by the results.

The results of the study support both the fourth and fifth hypotheses. The fourth hypothesis, the market value of the firm is positively related to effort, is supported by all of the estimations performed using regression model 9. This support is consistent across reporting method. The support for the fifth hypothesis, the change in market value due to a change in effort increases as the ability to discover and extent proven reserves increases, is not consistent across reporting methods. Only the results for FC firm estimations are supportive (see Tables 11A and 11B).

In addition, control variables, earnings per share at time *t* (x_t), and book value per share at time *t-1* (y_{t-1}) are significant for all estimation performed using the pooled sample and for all estimation performed using only SE firms. For estimation performed using only FC firms the three control variable book value per share at time *t* (y_t), x_t, and y_{t-1} are significant. Finally, the results of Davidson and Mackinnon's *J* Test for nonnested models indicates that information concerning a firm's effort exerted and ability to discover or extend proven reserves are more important than the proven reserves in place at time *t* for valuing FC firms. The results indicate the opposite for SE firms.

CHAPTER VI

CONCLUSION

This chapter is organized as follows. Section 6.1 presents a summary and discusses the results. Section 6.2 provides a discussion of the implications the study has for future research. Extensions of the study are identified in section 6.3. Finally, section 6.5 discusses the limitations of the study.

6.1 Summary and Discussion of Results

The purpose of this dissertation is to study the relationship between "Disclosures about Oil and Gas Producing Activities," as required by SFAS No. 69 and the market value of oil and gas firms. The primary focus of the research is to determine if reserve quantity disclosures contained value-relevant information beyond earnings and book value.

Using Ohlson's (1991) model to provide an empirical framework, five hypotheses are developed. The first three hypotheses related to the value-relevance of reserves in place at time *t*. Hypothesis 1 predicted that the market value of the firm is positively related to proven reserves. The results of the study clearly support this hypothesis. This is in contrast to the prior studies of Clinch and Magliolo (1992), and Spear (1994a) which did not find results for total proven reserves. However, the results are not consistent across conversion methods. When proven reserves are measured in BOEs-energy the estimations performed using the pooled sample, FC firms, and SE firms all show supportive results. Only FC firms have supportive results when proven reserves are measured in BOEs-revenue. This does not mean that an energy-based conversion method is superior to a revenue-based conversion method. This result could simply be a reflection of an energy-based conversion method being the method of choice for investors in the oil and gas industry. When proven reserves of oil and proven reserves of gas are entered as separate variables, proven reserves of gas is significant for FC firms and proven reserves of oil is significant for SE firms. This is consistent with FC firms being smaller firms which operate primarily in the United States where oil deposits are not as abundant whereas SE firms are larger firms which operate internationally where deposits of oil are more abundant.

The second and third hypotheses predict that the market value of the firm is positively related to proven developed reserves and proven undeveloped reserves, respectively. The results support only the second hypothesis. Similar to the results for the first hypothesis, when proven developed reserves of oil and proven developed reserves of gas are entered as separate variables proven developed reserves of gas is significant for FC firms and proven developed reserves of oil is significant for SE firms. The results of the second and third hypotheses are consistent with proven undeveloped reserves being both harder to estimate and less valuable than proven developed reserves.

The last two hypotheses relate to the future discovery and extension of proven reserves. Hypothesis 4, the market value of the firm is positively related to effort, is supported by the results of the study. This support is consistent across reporting methods. However, the support for the fifth hypothesis, the change in market value due to a change in effort increases as the ability to discover and extend proven reserves increases, is not consistent across reporting methods. Only the results for FC firms are supportive. One possible explanation for this hypothesis not being supported by SE firms is that they all have approximately the same ability to discover and extend proven reserves. A second possible explanation is related to the SE reporting method. Under the SE method, a firm capitalizes only those prediscovery costs that can be related directly to revenue producing wells. The remaining prediscovery costs are expensed. Therefore, it is possible that book value and earnings contain a measure of ability for SE firms.

Finally, the results of the study indicate that proven reserves in place at time *t* are more relevant for valuing SE firms than are their effort exerted and ability to discover and extend proven reserves. This is the opposite of the results for FC firms. Effort and ability are more relevant than proven reserves in place at time *t* for valuing FC firms. Again, these results are consistent with the characteristics of FC and SE firms. Malmquist (1990) provides evidence that the greater the proportion of a firm's resources devoted to drilling and exploration the greater the likelihood the firm will choose the FC reporting method. Consequently, effort and ability would be more value-relevant for these firms. Malmquist (1990) also provides evidence that the greater the proportion of a firm's resources devoted to producing the greater the likelihood the firm will choose the SE reporting method. It stands to reason that proven reserves in place at time *t* would be more value-relevant for such a firm as the firm cannot produce without proven reserves.

In conclusion, the results of the study have implications for standard setting bodies. First, proven reserve quantities are value-relevant and therefore should continue to be disclosed. Second, the results indicate that proven developed reserves are value-relevant while proven undeveloped reserves are not. The results also indicate that there is a benefit to the separate disclosure of proven reserves of oil and gas. Based on this evidence the standards setting bodies may consider reevaluating the reserve-value disclosure. It is possible that there would be a benefit to having a separate reserve-value disclosure for oil and for gas. In addition, calculating the reserve-value measure using only proven developed reserves should also be considered. Finally, the standard setting bodies should consider a standardized disclosure for ability (finding costs) as called for by Gaddis (1990).

6.2 Implications for Future Research

The results of this study have several implications for future research. First, the differences between FC and SE firms deserves further attention. Are the reporting methods causing a difference in the way FC and SE firms are valued or are the reporting methods acting as a surrogate for other firm characteristics. Second, the difference between conversion methods could be further analyzed to see if an energy-based method is actually superior or if the results of the study are because of industry practices. Finally, surrogates for ability could be analyzed to find one that best predicts the discovery and extension of proven reserves and therefore would be the most relevant for valuing oil and gas firms.

6.3 Extensions

Several extensions to this study also exist. First, the concept of risk could be incorporated into the model. Second, when more data is available, time series analysis could be employed. This time series analysis could examine both the hypothesis in this study as well as the ability of proven reserves to predict future earnings. Similarly, the ability of proven reserves and exploratory costs to predict discoveries and extensions of proven reserves could be investigated using a time series analysis. Finally, this study could be extended to examine the value-relevance of other supplementary disclosures required by SFAS No. 69.

6.5 Limitations

As any other study, this one is subject to limitations. Similar to previous studies using reserve disclosure data, this study is limited because of data problems. First, the reserve quantity disclosures are unaudited. If the data from these disclosures has measurement error, it can bias regression coefficients and affect the resulting inferences. Second, collinearity between the test variables biases the study against getting supportive results. The study is also limited because there is no required uniform disclosure to use as a surrogate for ability. Gaddis (1990) lists several problems related to using surrogates for ability and calls for a required standardized measure to be disclosed. Finally, because the study used a short time period, the generalizability of the results are limited.

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APPENDIX A1

Proof of the valuation function (2) given assumption (A1), assumption (A2a), and assumption (A3).

Define the 2 x 2 matrix

$$MV \equiv R_F^{-1} \begin{bmatrix} \omega & 1 \\ 0 & \gamma \end{bmatrix}$$

The information dynamics, assumption (A3), can be expressed as

$$(\tilde{x}_{t+1}^{a}, \tilde{\nu}_{t+1}) = R_F MV(x_t^{a}, \nu_t) + (\tilde{\varepsilon}_{1t+1}, \tilde{\varepsilon}_{2t+1}),$$

and

$$R_F^{-\tau} E_t[\tilde{x}_{t+\tau}^{a}] = (1,0) MV^{\tau}(x_t^{a}, \nu_t).$$

Given assumption (A1) and assumption (A2a) one can use (1) and combine it with the last expression:

$$MV_t - y_t = \sum_{\tau=1}^{\infty} R_F^{-\tau} E_t[\tilde{x}_{t+\tau}^{a}] = (1,0)[MV + MV^2 + \ldots](x_t^{a}, \nu_t)$$

$$\equiv (\alpha_1, \alpha_2)(x_t^{a}, \nu_t).$$

The sum of the matrix series $MV + MV^2 + \ldots$ converges because the maximum characteristic root of MV is less than one. Using routine algebra, one shows that the sum of the series equals $MV[I-MV]^{-1}$. One obtains

$$(\alpha_1, \alpha_2) = (1,0) MV[I - MV]^{-1},$$

and, via explicit calculation,

$$\alpha_1 = \omega/(R_F - \omega),$$

$$\alpha_2 = R_F/(R_F - \omega)(R_F - \gamma).$$

APPENDIX A2

The problem is to max V_0 by choosing q_t. The Lagrangian function is

$$L = \sum_{t=0}^{N} (p_t - c_0)q_t/(1 + r)^t - \lambda(\sum_{t=0}^{N} q_t - R_0)$$

The following first-order conditions result:

$$\frac{\partial L}{\partial q_0} = (p_0 - c_0) - \lambda = 0$$

$$\frac{\partial L}{\partial q_1} = \frac{p_1 - c_0}{(1 + r)} - \lambda = 0$$

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$$\frac{\partial L}{\partial q_N} = \frac{p_N - c_0}{(1 + r)^N} - \lambda = 0$$

$$\frac{\partial L}{\partial \lambda} = \sum_{t=0}^{N} q_t - R_0 = 0$$

These first-order conditions can be summarized as follows:

$$(p_t - c_0)/(1 + r)^t = \lambda, \qquad t=0,\ldots,N,$$

$$\sum_{t=0}^{N} q_t = R_0$$

APPENDIX B - Correlation Matrices

Correlation Matrices
Regression Model 1
BOEs-Energy

Variable	Price	y_t	x_t	y_{t-1}	R	EXP
Panel A: Pooled Sample						
Price	1.00					
y_t	0.82	1.00				
x_t	0.39	0.25	1.00			
y_{t-1}	0.75	0.94	0.01	1.00		
R	0.58	0.64	0.08	0.62	1.00	
EXP	0.54	0.63	-0.07	0.66	0.61	1.00
ADD	0.33	0.35	-0.01	0.36	0.53	0.45
Panel B: Full Cost Sample						
Price	1.00					
y_t	0.86	1.00				
x_t	0.40	0.27	1.00			
y_{t-1}	0.82	0.94	0.08	1.00		
R	0.40	0.35	0.03	0.31	1.00	
EXP	0.40	0.33	-0.15	0.36	0.47	1.00
ADD	0.33	0.24	0.04	0.20	0.60	0.34
Panel C: Successful Efforts Sample						
Price	1.00					
yt	0.80	1.00				
x_t	0.40	0.25	1.00			
y_{t-1}	0.73	0.94	-0.02	1.00		
R	0.60	0.67	0.09	0.64	1.00	
EXP	0.56	0.68	-0.06	0.70	0.62	1.00
ADD	0.30	0.36	-0.03	0.38	0.52	0.46

Correlations Matrices
Regression Model 1
BOEs-Revenue

Variable	Price	y_t	x_t	y_{t-1}	R	EXP
Panel A: Pooled Sample						
Price	1.00					
y_t	0.82	1.00				
x_t	0.39	0.25	1.00			
y_{t-1}	0.75	0.94	0.01	1.00		
R	0.55	0.63	0.17	0.58	1.00	
EXP	0.54	0.63	-0.07	0.66	0.59	1.00
ADD	0.35	0.41	0.09	0.38	0.67	0.45
Panel B: Full Cost Sample						
Price	1.00					
y_t	0.86	1.00				
x_t	0.40	0.27	1.00			
y_{t-1}	0.82	0.94	0.08	1.00		
R	0.35	0.29	0.06	0.24	1.00	
EXP	0.40	0.33	-0.14	0.36	0.43	1.00
ADD	0.31	0.22	0.05	0.17	0.58	0.34
Panel C: Successful Efforts Sample						
Price	1.00					
y_t	0.80	1.00				
x_t	0.40	0.25	1.00			
y_{t-1}	0.73	0.94	-0.02	1.00		
R	0.56	0.67	0.18	0.60	1.00	
EXP	0.56	0.68	-0.06	0.70	0.59	1.00
ADD	0.34	0.43	0.09	0.40	0.68	0.46

Correlations Matrices
Regression Model 2
BOEs-Energy

Variable	Price	y_t	x_t	y_{t-1}	DEV	UDEV	EXP
Panel A: Pooled Sample							
Price	1.00						
y_t	0.82	1.00					
x_t	0.39	0.25	1.00				
y_{t-1}	0.75	0.94	0.01	1.00			
DEV	0.60	0.64	0.09	0.63	1.00		
UDEV	0.41	0.49	0.06	0.47	0.70	1.00	
EXP	0.54	0.63	-0.07	0.66	0.61	0.48	1.00
ADD	0.33	0.35	-0.01	0.36	0.47	0.57	0.45
Panel B: Full Cost Sample							
Price	1.00						
y_t	0.86	1.00					
x_t	0.40	0.27	1.00				
y_{t-1}	0.82	0.94	0.08	1.00			
DEV	0.42	0.36	0.03	0.34	1.00		
UDEV	0.12	0.11	0.01	0.04	0.33	1.00	
EXP	0.40	0.33	-0.15	0.36	0.47	0.19	1.00
ADD	0.34	0.24	0.04	0.21	0.50	0.59	0.35
Panel C: Successful Efforts Sample							
Price	1.00						
y_t	0.80	1.00					
x_t	0.40	0.25	1.00				
y_{t-1}	0.73	0.94	-0.02	1.00			
DEV	0.62	0.67	0.09	0.65	1.00		
UDEV	0.42	0.51	0.06	0.49	0.71	1.00	
EXP	0.56	0.68	-0.06	0.70	0.61	0.49	1.00
ADD	0.30	0.36	-0.03	0.38	0.46	0.57	0.46

Correlations Matrices
Regression Model 2
BOEs-Revenue

Variable	Price	y_t	x_t	y_{t-1}	DEV	UDEV	EXP
Panel A: Pooled Sample							
Price	1.00						
y_t	0.82	1.00					
x_t	0.39	0.25	1.00				
y_{t-1}	0.75	0.94	0.01	1.00			
DEV	0.57	0.65	0.17	0.60	1.00		
UDEV	0.41	0.51	0.14	0.46	0.82	1.00	
EXP	0.53	0.63	-0.07	0.66	0.60	0.47	1.00
ADD	0.35	0.41	0.09	0.38	0.63	0.68	0.45
Panel B: Full Cost Sample							
Price	1.00						
y_t	0.86	1.00					
x_t	0.40	0.27	1.00				
y_{t-1}	0.82	0.94	0.08	1.00			
DEV	0.39	0.33	0.07	0.30	1.00		
UDEV	0.07	0.05	0.02	-0.02	0.41	1.00	
EXP	0.40	0.33	-0.15	0.36	0.45	0.16	1.00
ADD	0.31	0.22	0.05	0.17	0.50	0.55	0.34
Panel C: Successful Efforts Sample							
Price	1.00						
y_t	0.80	1.00					
x_t	0.40	0.25	1.00				
y_{t-1}	0.73	0.94	-0.02	1.00			
DEV	0.59	0.68	0.18	0.62	1.00		
UDEV	0.43	0.55	0.16	0.48	0.83	1.00	
EXP	0.56	0.68	-0.06	0.70	0.61	0.49	1.00
ADD	0.34	0.43	0.09	0.40	0.64	0.69	0.46

Correlations Matrices
Regression Model 3

Variable	Price	y_t	x_t	y_{t-1}	RO	RG	EXP
Panel A: Pooled Sample							
Price	1.00						
y_t	0.82	1.00					
x_t	0.39	0.25	1.00				
y_{t-1}	0.75	0.94	0.01	1.00			
RO	0.57	0.54	0.16	0.50	1.00		
RG	0.44	0.54	0.01	0.54	0.40	1.00	
EXP	0.54	0.63	-0.07	0.66	0.57	0.48	1.00
ADD	0.33	0.35	-0.01	0.36	0.29	0.56	0.45
Panel B: Full Cost Sample							
Price	1.00						
y_t	0.85	1.00					
x_t	0.40	0.27	1.00				
y_{t-1}	0.82	0.94	0.08	1.00			
RO	0.03	0.02	0.00	-0.02	1.00		
RG	0.46	0.40	0.04	0.38	0.20	1.00	
EXP	0.40	0.33	-0.15	0.36	0.24	0.44	1.00
ADD	0.34	0.24	0.04	0.21	0.22	0.60	0.34
Panel C: Successful Efforts Sample							
Price	1.00						
y_t	0.80	1.00					
x_t	0.40	0.25	1.00				
y_{t-1}	0.73	0.94	-0.02	1.00			
RO	0.64	0.58	0.18	0.53	1.00		
RG	0.41	0.54	0.00	0.54	0.37	1.00	
EXP	0.56	0.68	-0.06	0.70	0.60	0.46	1.00
ADD	0.30	0.36	-0.03	0.38	0.28	0.54	0.46

Correlations Matrices
Regression Model 4

Variable	Price	y_t	x_t	y_{t-1}	DRO	UDRO	DRG	UDRG	EXP
Panel A: Pooled Sample									
Price	1.00								
y_t	0.82	1.00							
x_t	0.39	0.25	1.00						
y_{t-1}	0.75	0.94	0.01	1.00					
DRO	0.59	0.56	0.14	0.53	1.00				
UDRO	0.38	0.34	0.15	0.30	0.63	1.00			
DRG	0.47	0.54	0.03	0.55	0.45	0.21	1.00		
UDRG	0.28	0.41	-0.03	0.42	0.28	0.23	0.71	1.00	
EXP	0.54	0.63	-0.07	0.66	0.60	0.37	0.48	0.38	1.00
ADD	0.33	0.35	-0.01	0.36	0.29	0.19	0.48	0.63	0.45
Panel B: Full Cost Sample									
Price	1.00								
y_t	0.85	1.00							
x_t	0.40	0.27	1.00						
y_{t-1}	0.82	0.94	0.08	1.00					
DRO	0.09	0.09	0.00	0.05	1.00				
UDRO	-0.11	-0.12	-0.01	-0.18	0.53	1.00			
DRG	0.45	0.39	0.04	0.38	0.28	-0.03	1.00		
UDRG	0.26	0.26	0.01	0.19	0.02	0.21	0.40	1.00	
EXP	0.40	0.33	-0.15	0.36	0.28	0.07	0.44	0.21	1.00
ADD	0.34	0.24	0.04	0.21	0.19	0.21	0.51	0.66	0.34
Panel C: Successful Efforts Sample									
Price	1.00								
y_t	0.80	1.00							
x_t	0.40	0.25	1.00						
y_{t-1}	0.73	0.94	-0.02	1.00					
DRO	0.65	0.60	0.17	0.55	1.00				
UDRO	0.43	0.38	0.17	0.33	0.61	1.00			
DRG	0.45	0.56	0.02	0.56	0.43	0.20	1.00		
UDRG	0.26	0.41	-0.04	0.42	0.24	0.18	0.75	1.00	
EXP	0.56	0.68	-0.06	0.70	0.62	0.38	0.46	0.38	1.00
ADD	0.30	0.36	-0.03	0.38	0.29	0.16	0.46	0.63	0.46

APPENDIX C - Glossary

This glossary provides definitions for various technical terms relating to the oil and gas industry that are used in this proposal. The definitions are taken from SFAS No. 19. In some cases a summarized version is presented.

Development costs - Development costs are incurred to obtain access to proven reserves and to provide facilities for extracting, treating, gathering, and storing the oil and gas. (par. 21)

Exploration - Exploration involves (a) identifying areas that may warrant examination and (b) examining specific areas that are considered to have prospects of containing oil and gas reserves, including drilling exploratory wells and exploratory-type stratigraphic test wells. (par. 16)

Exploration costs - Exploration costs may be incurred both before acquiring the related property and after acquiring the related property. (par. 16) Principle types of exploration costs are: (a) costs of topographical, geological, and geophysical studies, rights of access to properties to conduct those studies, and salaries and other expenses of geologists, geophysical crews, and others conducting those studies; (b) costs of carrying and retaining undeveloped properties, such as delay rentals, ad valorem taxes on the properties, legal costs for title defense, and maintenance of land and lease records; (c) dry hole contributions and bottom hole contributions; (d) costs of drilling and equipping exploratory wells; (e) costs of drilling exploratory-type stratigraphic test wells. (par. 17)

Extensions, discoveries, and other additions - Additions to an enterprise's proven reserves that result from (i) extensions of the proven acreage of previously discovered (old) reservoirs through additional drilling in periods subsequent to discovery, and (ii) discovery of new fields with proven reserves or of new reservoirs of proven reserves in old fields. (par. 51)

Field - An area consisting of a single reservoir or multiple reservoirs all grouped on or related to the same individual geological structural feature and/or stratigraphic condition. Two or more reservoirs in a field may be separated vertically by intervening impervious strata, or laterally by local geologic barriers, or by both. (par. 272)

Lifting costs - Another term for production costs. (par. 24)

Net quantities of proven reserves - Net quantities of reserves include those relating to the enterprise's operating and nonoperating property interests (i.e., interests in properties operated by others). Net quantities shall not include reserves relating to interests of others in properties owned by the enterprise. (par. 50)

Production - Production involves lifting the oil and gas to the surface and gathering, treating, field processing, (as in the case of processing gas to extract liquid hydrocarbons), and field storage. (par. 23)

Production costs - Production costs are those costs incurred to operate and maintain an enterprise's wells and related equipment and facilities. They become part of the cost of oil and gas produced. (par. 24)

Proven developed reserves - Reserves which can be expected to be recovered through existing wells with existing equipment and operating methods. (par. 271)

Proven reserves - Those quantities of crude oil, natural gas, and natural gas liquids which, upon analysis of geologic and engineering data, appear with reasonable certainty to be recoverable in the future from known oil and gas reservoirs under existing economic and operating conditions. (They are also referred to as proven reserves.) Depending upon their status of development, such reserves are subdivided into proven developed reserves and proven undeveloped reserves. (par. 271)

Proven undeveloped reserves - Reserves which are expected to be recovered from new wells on undrilled acreage, or from existing wells where a relatively major expenditure is required for recompletion. (par. 271)

Reservoir - A porous and permeable underground formation containing a natural accumulation of producible oil or gas that is confined by impermeable rock or water barriers and is individual and separate from other reservoirs. (par. 273)

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