Oil and Natural Gas Reserve Prices: Addendum to CEEPR WP 03-016; Including Results for 2003 and Revisions to 2001

by

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Introduction. A working paper entitled “Oil and Natural Gas Reserve Prices 1982-2002: Implications for Depletion and Investment Cost” was published in October 2003 (cited hereafter as Adelman & Watkins [2003]). Since then we have obtained data for 2003 and estimated oil and natural gas reserve prices for that year. We have also revised our previous estimates of reserve prices for 2001.

This addendum paper reports on the nature and significance of the results for 2003 and the revisions to 2001. We have also extended the analysis by adding two new features. First is the expression of reserve prices in real terms – previously we had only reported nominal prices. Second, we have estimated levelized or constant field prices that appear to underlie reserve prices, for each year. We refer to these as planning prices. Previously we had only published estimated growth rates in field prices from levels prevailing for a given year, congruent with our estimates of reserve prices.

Section 1 of this Addendum paper highlights the 2003 results. Section 2 discusses the revisions for year 2001. Section 3 outlines the nature of the analytical extensions, presents the results, and discusses what they show. Concluding remarks are in Section 4.

Adelman & Watkins [2003] included an extensive set of tables in Appendices. The revisions to all these tables to include 2003 and revised 2001 data are attached here as Appendices.

This paper is to be read in conjunction with, not as a substitute for, Adelman & Watkins [2003]: analysis and description in the 2003 paper is not repeated here.


Transaction Characteristics. As before, the source of our data on reserve transactions was the Scotia Group. The number of usable transactions for 2003 was 40, the lowest since 19861. Of these, four were identified as outliers (for outlier criteria, see discussion in Adelman & Watkins [2003, pp13-14]).

1 Of the 40 transactions, 5 were ‘pure’ oil, 23 ‘pure’ gas (‘pure’ refers to transactions where only oil or gas reserves were identified).
In common with all other years of the data set, the distribution of transaction values was skewed to the left (though less so than for other years) and the hypothesis of log Normality was not rejected. The four outliers were of larger than average value: the mean transaction value fell from some $150mm for the 40 observations (before exclusion of outliers) to $120 mm for the 36 observations (after exclusion of outliers).

Regression Results. Linear regression (without a constant) of all transaction values on oil and natural gas reserve volumes disclosed an oil reserve price of $9.87/bbl and $1.12/mcf for gas. After elimination of the four outliers, the reserve prices changed to $8.17/bbl and $1.19/mcf respectively.

These values marked a very noticeable increase compared with 2002 of $2.43/bbl or about 40 per cent for oil, $0.31/mcf or 35 per cent for gas (variation is for results after exclusion of outliers).

Reserve Status. As in Adelman & Watkins [2003] tests were made of whether reserves were on production or not would influence reserve values. In the case of oil, the 2003 observation set (excluding outliers) did not provide evidence that reserves on production exhibited higher values than those that were seemingly fallow. In contrast, for gas the conclusion was that shut-in reserves had higher reserve prices than those on production. If valid, we ascribe this result to expected appreciation of in-ground reserves by the time they are produced, without dilution by interim production.

Influence of R/P Ratio. Year 2003 did not provide evidence that, other things equal, the higher the R/P ratio, the lower the reserve price. In the case of oil, although the coefficient intended to detect any such influence had the expected sign, it was insignificant; for gas the corresponding coefficient was virtually zero.

Reserve Prices and Field Prices. Our interest here relates to the influence of field prices (prices for flowing oil) on in-ground prices. Addition of 2003 to the regression of reserve prices on contemporary prices, prices lagged one year, and prices lagged two years did not appreciably affect the earlier results. Oil reserve prices remained positively and significantly affected by field prices: about 15 per cent of any change in field prices would be reflected in reserve prices (but the degree of linear fit of the three oil equations remained modest).

Natural gas reserve prices were positively related to field prices; moreover, in the case of contemporary prices and prices lagged one year, the coefficient was now significant; about 10 per cent of any change in field prices would be reflected in reserve prices (as before, the linear fit remained trivial).

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2 The adjusted R$^2$ was 0.93. Both reserve values were strongly significant. Estimation of the equation with an intercept revealed it was not significant.
3 Adjusted R$^2$ was 0.97; both reserve coefficients highly significant. An intercept, when inserted in the equation, was found to be negative and significant. However, it had little impact on the reserve coefficients in comparison with its value when the intercept was suppressed.
4 The results on reserve prices are discussed in more detail in Section 3.
Reserve Prices and Hotelling Values. Hotelling’s valuation principle (HVP) sees the in-ground price of a mineral as equal to the prevailing net field price (field price less operating cost). The 2003 Hotelling oil reserve value was more than double our estimated reserve price, equivalent to over 20 standard deviations above it. As with almost every other year, the results for 2003 do not support the HVP. The conclusions for gas were similar: the ratio for the HV to the reserve price was 2.7, representing a spread between them of 32 standard deviations.

Implicit Growth Rates in Prices. Implicit growth rates in field prices embedded in reserve prices can be estimated, given some simplifying assumptions. For oil, the reserve price in 2003 of $8.17/bl did not seem to anticipate any change in field prices, up or down (the 95 per cent confidence interval was about three percentage points either side). The natural gas value of $1.45/mcf appeared to reflect a seven per cent annual reduction in field prices (the confidence interval was a symmetrical two percentage points)\(^5\).

Returns to Holding Reserves. The HVP implies in-ground prices increase in adjacent years at industry’s discount rate. In 2003, the rise in both oil and gas reserve prices exceeded the discount associated with minimum risk by a considerable margin.


The results for 2001 as published in Adelman & Watkins [2003] showed an increase in reserve values over year 2000 values of about 19 per cent in the case of oil, but more than doubled in the case of natural gas (which then fell as dramatically in 2002). The numbers quoted related to the equation without a constant and excluding outliers\(^6\).

Such an unusual spike in natural gas prices suggested revisiting the underlying transaction data. We examined all the 61 observations used in Adelman & Watkins [2003] to check again for irregularities, unusual values, transactions that involved international assets, transactions that employed ‘barrels of oil equivalence’ and so forth.

This additional scrutiny identified 11 observations of doubtful parentage, and these were added to the list of excluded transactions. Hence the original 61 observations were reduced to 50. Of the 50, four were identified as outliers, leaving 46 observations after their exclusion. Of the original 61 observations, nine outliers had been identified, leaving 52 observations after outliers. Thus the difference between the original number of observations excluding outliers and the corresponding revised number is six (52 less 46). Hence of the original observations, on a net basis five outliers (9 less 4) were subsequently eliminated from the data set\(^7\).

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\(^5\) In Section 3 we estimate implicit levelized field prices embedded in reserve prices.
\(^6\) See Table B-2a, Adelman & Watkins [2003, p66].
\(^7\) It so happens that these five observations identified as outliers in Adelman & Watkins [2003] were five of the 11 observations eliminated from the data set in the review.
Transaction Characteristics. The reduced data set did not shift the leftward distribution of transaction values; log Normality would not be rejected for the 50 observation set. The four outliers were of larger than average value: the mean transaction value fell from $127\text{mm}$ for the 52 observations to $101\text{mm}$ for the 46 observations. And in physical terms, the mean reserve sizes fell.

Regression Results. Linear regression (without a constant) of the 50 transaction values on oil and natural gas reserve volumes disclosed an oil reserve value of $6.40/\text{bl}$ and $1.32/\text{mcf}$ for gas\(^8\). After elimination of the four outliers, these reserve values changed to $5.75/\text{bl}$ and $1.45/\text{mcf}$ respectively\(^9\).

The revised year 2001 oil reserve value of $5.75/\text{bbl}$ (after exclusion of outliers) was an increase of about a third over the original value of $4.21/\text{bbl}$ in Adelman & Watkins [2003]. The natural gas reserve value fell from $1.68/\text{mcf}$ to $1.45/\text{mcf}$, or by some 15 per cent. In short, the original analysis tended to underestimate oil reserve values but overestimate gas reserve values.

Reserves Status. Tests of whether reserve prices were influenced by reserves being on production or not disclosed no evidence that reserves on production exhibited higher in-ground values than those seemingly fallow. In the case of oil this result was consistent with the original results; in contrast, for gas the original results had suggested that shut-in reserves had significantly higher reserve prices than those on production.

Influence of R/P Ratio. For oil, the coefficient intended to detect whether R/P ratios influenced reserve values now had the expected (negative) sign, although it was insignificant (in the original results it had been positive but insignificant). For gas, the corresponding coefficient remained negative and significant.

Reserve Prices and Field Prices. The revised 2001 reserve prices had little impact on the results after inclusion of year 2003, reported on above. For oil, the effect of a change in field prices on reserve prices went up slightly to 16 per cent, and the degree of equation fit improved marginally. For gas, there was no appreciable change.

Reserve Prices and Hotelling Values. The ratio of the Hotelling value to the oil reserve prices remained well over two (2.5), although falling from 3.4 beforehand. The spread between the two values was 8.7 standard deviations, a result that continued to provide no support for the HVP. In the case of gas the ratio increased from 1.6 originally to 1.8, with a spread of 7.5 standard deviations – again, no support for the HVP.

Implicit Growth Rates in Prices. The revised 2001 oil reserve price was associated with an increase in the implicit annual growth rate in field prices from minus

\(^8\)The adjusted $R^2$ was 0.98. Both reserve values were strongly significant. When the equation was estimated with an intercept, the latter was insignificant.

\(^9\)Adjusted $R^2$ was 0.97; both reserve coefficients highly significant. An intercept, when inserted in the equation, was found to be negative and significant. However, it had little impact on the reserve coefficients estimated when it was suppressed.
nine per cent to minus two per cent (the 95 per cent confidence interval was wide at about 10 percentage points either side). The natural gas value of $1.45/mcf suggested a two per cent annual growth rate in field price, below the four per cent previously (the confidence interval is about a symmetric four percentage points, modestly higher than beforehand).

**Returns to Holding Reserves.** The increase in the oil reserve value enhances the ‘surplus’ apparent achieved risk premium over minimum levels already observed with the original data. In the case of natural gas, the achieved risk premium fell with the lower gas reserve value, but still remained comfortably above minimum levels.

3. **Extensions to Analysis.**

In this section we report on reserve prices after adjustment for inflation and comment on the trends revealed. We also specify estimation of levelized field prices and review those results.

**Reserve Values after Adjustment for Inflation.** In Adelman & Watkins [2003] all estimated reserve values were shown in money-of-the-day terms. Now we display them also in real terms. To do this, three indexes were considered: the US Consumer Price Index (CPP); the US GDP Price Index (GDPPI); and the US Producer Price Index (PPI). Reserve values are an alternative to piecemeal sales at wholesale prices, hence a retail price index would not be suitable. The GDPPI is preferable to the CPI, but its breadth is a disadvantage here. The PPI was selected as the best option.

The oil reserve values in $/bbl are shown in Table 1 and plotted in Figure 1; those for natural gas (in $/mcf) are listed in Table 2 and plotted in Figure 2. The estimates in the tables and plots are with outliers excluded and without an intercept. They are shown in both nominal and real terms, with the adjustment for inflation made by applying the US producer price index (2003 = 1.0). Adjustments using the GDPPI or CPI index resulted in higher real values than under the PPI.

Figure 1 reveals no visible secular trend in oil reserve prices, 1982-2003. Sometimes prices fall, sometimes they rise, as they have recently – but to levels in 2003 only marginally higher than at the previous peak in 1985 in money-of-the-day terms.

In real terms, oil prices tended to fall from the mid-1980s until the mid-1990s. Between then and year 2000 they were quite flat. Since year 2000 reserve prices have moved to distinctly higher levels, as field prices used in company evaluations have increased. This registered OPEC’s new found quota discipline and resulting ability to keep wellhead prices comfortably above $20/bbl. Nevertheless the estimated 2003 oil reserve price after adjustment for inflation is still around 20 per cent below the 1985 peak.

Figure 2 shows close to a plateau in natural gas reserve prices from 1986 to year 2000 in terms of money-of-the-day. Since then they have risen, including an unusual blip

**Table 1: Estimates of In-Ground Crude Oil Prices, United States, 1982-2003**

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(1) Expressed in US$2003 using US Producer Price Index

**Table 2: Estimates of In-Ground Natural Gas Prices, United States, 1982-2003**

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<tr>
<td>2003</td>
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(1) Expressed in US$2003 using US Producer Price Index
Figure 1: Estimates of US Oil Reserve Prices, 1982-2003

Figure 2: Estimates of US Natural Gas Prices, 1982-2003
**Levelized Field Prices Implicit in Reserve Prices.** In Adelman & Watkins [2003], for any given level of reserve prices we derived implicit field price expectations. The approximation was expressed as expected growth rates from prevailing field prices – negative or positive.

Another way of looking at field prices seemingly embedded in reserve prices is to express them as equivalent constant prices, that is, as levelized prices over the reserve’s life. This approach has more in common with industry practice in evaluating reserve properties of adopting a flat price for estimating cash flow, rather than to assume a price trend. The flat price might be in nominal or real terms. The industry vernacular refers to price used for project appraisal as the ‘price deck’.

After making some simplifying assumptions, the general expression for the uniform ‘planning’ price implicit in the price of a reserve in the ground is given by:

\[ P_L = \frac{V(a + i)}{a} + c. \]  

where \( P_L \) = uniform planning field price  
\( a \) = production decline rate, percentage per year  
\( i \) = discount rate  
\( V \) = reserve price  
\( c \) = unit extraction cost.

This formula can be derived from expression (6) in Adelman & Watkins [2003, p32] after setting \( g \), the growth rate equal to zero, and then solving for price\(^{10}\).

The results of applying (1) are shown in Table 3 for both oil and natural gas. The respective series are plotted in Figures 3 (oil) and 4 (gas). Each plot also shows actual field prices.

From the mid 1980s to the late 1990s fixed planning prices for oil were close to actual prices; but from 1999 to 2002 planning prices were consistently below actual prices – the implication was that parties making oil reserve transactions did not see realized field prices as being sustainable. In 2002 and especially 2003 that mood had seemingly changed, and indeed in 2003 oil planning prices approximated actual prices.

In the case of natural gas, from the mid-1980s to the mid 1990s planning prices were consistently above actual field prices, an indication that corporations misjudged the impact of deregulation. From the mid 1990s on, there was a close approximation between planning and actual prices, except in 2003, when actual field prices appreciably exceeded planning prices.

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\(^{10}\) The planning prices estimated from equation (1) are related to those expressed in terms of growth rates (see earlier) in the following way: an expected positive growth rate in field prices would be associated with a planning price that exceeded the actual field price for the year in question, and vice versa.
Table 3: Oil and Natural Gas Planning Prices, 1982-2003

<table>
<thead>
<tr>
<th>Year</th>
<th>Oil ($/BBL)</th>
<th>Natural Gas ($/MCF)</th>
<th>Year</th>
<th>Oil ($/BBL)</th>
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<td>2.94</td>
<td>2002</td>
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Figure 3: Oil Planning Prices (Derived from Reserve Values) and Actual Field Prices, 1982-2003
4. **Concluding Remarks.**

Addition of the year 2003 to the data base, and revisions to previous estimates of reserve prices for 2001 do not alter the main character of the results in Adelman & Watkins [2003]. This applies to our findings on the influence of reserves status, R/P ratios and field prices on reserve prices. The Hotelling Valuation Principle continues to provide little or no clue on what industry pays for in-ground reserves.

Yet the reserve prices estimated for 2003 do inject new information on how industry is valuing reserve assets. The strong rise in oil reserve prices provides a clear indication that field prices in the mid $20s per barrel are viewed more as a floor than as a ceiling, and that prices in the teens are not countenanced. This picture is illustrated by the estimates of planning prices underlying the prices paid for developed reserves.

It also follows that if development costs have increased to a lesser degree than the 40 per cent increase in reserve prices estimated in 2003, then an additional margin is available to cover finding costs – increasing the attraction of more expensive sources of reserve additions.

Reassessment of reserve prices in 2001 suggested our earlier estimates were too low in for oil, too high for natural gas. Although we are now carrying a lower reserve price for natural gas, the sharp blip in comparison with year 2000 remains. This seems to be attributable to euphoria over the strong increases in field prices after 1999, before a collapse in 2002.
Some might conclude that the increase in oil reserve prices in 2003 was evidence of nascent shortages. This inference would be false. Tighter world supply and resulting higher prices demonstrated OPEC’s improved ability to control a surplus, not its extinction. Greater OPEC discipline was not lost on market participants – it translated into amounts paid for reserves in the ground, amounts that were still below those paid in 1985, in real terms.

Explanation of higher prices being paid for natural gas reserves in 2003 does not parallel that for oil. While more of an international market is just being to emerge for natural gas, by far the main determinant of prices remains the conditions in North America. Here, higher prices do register tighter supply and a climb up the supply curve.

APPENDICES
Table A-1: Number of Identified Transactions

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Outliers are defined as follows:

For pure transactions, a reserve price more than two standard deviations for that year.
For mixed transactions, a transaction value more than two standard deviations away from the fitted value.
Transactions of value less than $0.55 per barrel or $0.10 per mcf, or greater than $27.50 per barrel or $5 per mcf.

Source: The Scotia Group M&A Database, January 2004
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The normality test used is Jarque-Bera; reject indicates that normality of the log distribution was rejected at 95% confidence level.

Source: The Scotia Group M&A Database, January 2004
## Table A-3: Summary Statistics for Transaction Values, Excluding Outliers

**[Millions of Nominal $, where relevant]**

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The normality test used is Jarque-Bera; reject indicates that normality of the log distribution was rejected at 95% confidence level.

Source: The Scotia Group M&A Database, January 2004
Table A-4: Summary Statistics for Pure Oil Transaction Values, Excluding Outliers  
[Millions of Nominal $, where relevant]

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The normality test used is Jarque-Bera; reject indicates that normality of the log distribution was rejected at 95% confidence level.

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The normality test used is Jarque-Bera; reject indicates that normality of the log distribution was rejected at 95% confidence level.

Source: The Scotia Group M&A Database, January 2004
Table A-6: Summary Statistics for Size of Oil Reserves, All Transactions
[Millions of Barrels, where relevant]

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The normality test used is Jarque-Bera; reject indicates that normality of the log distribution was rejected at 95% confidence level.

Source: The Scotia Group M&A Database, January 2004
Table A-7: Summary Statistics for Size of Natural Gas Reserves, All Transactions  
[BCFs, where relevant]

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The normality test used is Jarque-Bera; reject indicates that normality of the log distribution was rejected at 95% confidence level.

Source: The Scotia Group M&A Database, January 2004
### Table A-8: Summary Statistics for Reserve Size in Thermal Equivalence, All Transactions

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Trillion BTUs: 1 Trillion BTUs = 1 Billion Cubic Feet at 1,000 BTUs per cubic foot (TBTUs)
Thermal equivalence factor of 5.5 million BTUs per barrel used.

The normality test used is Jarque-Bera; reject indicates that normality of the log distribution was rejected at 95% confidence level.

Source: The Scotia Group M&A Database, January 2004
### Table A-9: Summary Statistics for Reserve Size in Thermal Equivalence, Excluding Outliers

[Trillion BTUs, where relevant]

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Trillion BTUs: 1 Trillion BTUs = 1 Billion Cubic Feet at 1,000 BTUs per cubic foot (TBTUs)
Thermal equivalence factor of 5.5 million BTUs per barrel used.

The normality test used is Jarque-Bera; reject indicates that normality of the log distribution was rejected at 95% confidence level.

Source: The Scotia Group M&A Database, January 2004
Table B-1a: Regression Results for All Transactions (No Constant)

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Note: Transaction values are regressed on reserves of oil (in bbls) and natural gas (in mcf).

Source: The Scotia Group M&A Database, January 2004
### Table B-1b: Regression Results for All Transactions (Constant Included)

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Note: Transaction values are regressed on reserves of oil (in bbls) and natural gas (in mcf).

Source: The Scotia Group M&A Database, January 2004
Table B-1c: Comparisons of Oil Regression Values with Pure Oil Values for All Transactions (No Constant)

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Source: The Scotia Group M&A Database, January 2004

Note: The pure oil value observations are weighted volumetrically by the barrels in each transaction for a given year. This is equivalent to summing the value of all pure transactions in a given year and dividing by the total volumes of oil reserves sold.
Table B-1d: Comparisons of Natural Gas Regression Values with Pure Gas Values for All Transactions  
(No Constant)

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Source: The Scotia Group M&A Database, January 2004

Note: The pure gas value observations are weighted volumetrically by the cubic feet in each transaction for a given year. This is equivalent to summing the value of all pure transactions in a given year and dividing by the total volumes of gas reserves sold.
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Source: The Scotia Group M&A Database, January 2004
**Table B-2b: Regression Results for All Transactions (Constant Included), Excluding Outliers**  
(with Robust Standard Errors, rather than OLS Standard Errors)

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Source: The Scotia Group M&A Database, January 2004
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Source: The Scotia Group M&A Database, January 2004
Table B-2d: Effect of Outliers on Reserve Coefficients
(No Constant)

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Source: The Scotia Group M&A Database, January 2004
Table B-2e: Comparisons of Oil Regression Values (No Constant) with Pure Oil Values, Excluding Outliers

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<th># Obs</th>
<th>Ratio of Estimated Oil Coefficient to Pure Transaction ppb</th>
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Source: The Scotia Group M&A Database, January 2004

Note: The pure oil value observations are weighted volumetrically by the barrels in each transaction for a given year. This is equivalent to summing the value of all pure transactions in a given year and dividing by the total volumes of oil reserves sold.
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Note: Beginning reserves indicate remaining reserves at January 1.

Source: EIA/DOE "US Crude Oil, Natural Gas, and Natural Gas Liquids Reserves"
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--- Insufficient data points.

Source: The Scotia Group M&A Database, January 2004

Note: The pure gas value observations are weighted volumetrically by the cubic feet in each transaction for a given year. This is equivalent to summing the value of all pure transactions in a given year and dividing by the total volumes of gas reserves sold.
Table C-2: Regression Results for Transactions with Information on Reserve Status (No Constant), Excluding Outliers

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--- Insufficient data points.

Note: Reserve status - whether reserves are on production or not.

Equation Specification:

\[
adj\text{price} = [a_1^o + a_2^oD_o]R_o + [a_1^g + a_2^gD_g]R_g
\]

where:
- \(adj\text{price}\) is transaction price (after elimination of non reserve assets)
- the 'o' superscript denotes oil
- the 'g' superscript denotes gas
- \(a_1\) and \(a_2\) are the two coefficients for each reserve being tested
- \(R\) denotes reserves sold
- \(D\) denotes dummy variable for reserves on production
Table C-3: Regression Results for Transactions with Information on R/P Ratios (No Constant), Excluding Outliers

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R/P ratio is the ratio of remaining reserves to annual production.

Equation Specification:

\[ \text{adjprice} = \left[ a_{1}^{o} + a_{2}^{o}H_{o} \right]R_{o} + \left[ a_{1}^{g} + a_{2}^{g}H_{g} \right]R_{g} \]

where:
- \( \text{adjprice} \) is transaction price (after elimination of non reserve assets)
- the 'o' superscript denotes oil
- the 'g' superscript denotes gas
- \( a_{1} \) and \( a_{2} \) are the two coefficients for each reserve being tested
- \( R \) denotes reserves sold
- \( H \) denotes the R/P ratio
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Sources:
Cols 2, 5 EIA/DOE "Monthly Energy Review" November 2004
Cols 3, 6 Table B2-a
**Table C-5: Regression Results: Reserve Prices and Field Prices**

**Reserve Prices Against Field Prices**

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**Reserve Prices Against First Differences in Field Prices**

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Note: A value of 0.00 implies negligible growth rates.

Sources:

(2) Production/Reserves Ratio, P/R, Table C-1.
(3) Adjusted Ratio (a), see text.
(4) Reserve Price (b), Table B-2a, Col 3.
(5) Regression Results.
(6) Operating Cost (c), 35% of field price.
(7) Field Price (p), Table C-4.
(8) Implicit Annual Growth Rate in Price, see text.
(9) Net Field Price, p-c, Column (7) - Column (6).
(10) HV to Reserve Price, Column (9) / Column (4).
(11) HV Spread: Standard Deviations, [Column (9) - Column (4)] / Column (5).
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Note: A value of 0.00 implies negligible growth rates.

Sources:

(2) Production/Reserves Ratio, P/R, Table C-1.
(3) Adjusted Ratio (a), see text.
(4) Reserve Price (b), Table B-2e, Col 4.
(5) Statistical Results.
(6) Operating Cost (c), 35% of field price.
(7) Field Price (p), Table C-4.
(8) Implicit Annual Growth Rate in Price, see text.
(9) Net Field Price, p-c, Column (7) - Column (6).
(10) HV to Reserve Price, Column (9) / Column (4).
(11) HV Spread: Standard Deviations, [Column (9) - Column (4)] / Column (5).
### Table D-3: Estimates of Hotelling Values and Price Expectations, Natural Gas

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<th>Operating Cost (c) $/mcf</th>
<th>Field Price (p) $/mcf</th>
<th>Implicit Annual Growth Rate in Price</th>
<th>Net Field Price: HV to Reserve Price $/mcf</th>
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Note: A value of 0.00 implies negligible growth rates.

Sources:

(2) Production/Reserves Ratio, P/R, Table C-1.
(3) Adjusted Ratio (a), see text.
(4) Reserve Price (b), Table B-2a, Col 5.
(5) Regression Results.
(6) Operating Cost (c), 35% of field price.
(7) Field Price (p), Table C-4.
(8) Implicit Annual Growth Rate in Price, see text.
(9) Net Field Price, p-c, Column (7) - Column (6).
(10) HV to Reserve Price, Column (9) / Column (4).
(11) HV Spread: Standard Deviations, [Column (9) - Column (4)] / Column (5).
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Note: A value of 0.00 implies negligible growth rates.

Sources:

(2) Production/Reserves Ratio, P/R, Table C-1.
(3) Adjusted Ratio (a), see text.
(4) Reserve Price (b), Table B-2f, Col 4.
(5) Statistical Results.
(6) Operating Cost (c), 35% of field price.
(7) Field Price (p), Table C-4.
(8) Implicit Annual Growth Rate in Price, see text.
(9) Net Field Price, p-c, Column (7) - Column (6).
(10) HV to Reserve Price, Column (9) / Column (4).
(11) HV Spread: Standard Deviations, [Column (9) - Column (4)] / Column (5).
## Table D-5: Confidence Limits for Implicit Growth Rate of Oil Prices

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</table>

Note: A value of 0.00 implies negligible growth rates.

Sources:

(2) Implicit Annual Growth Rate in Price, Table D-1, Col 8.
(3) See text.
(4) See text.
(5) See text.
(6) See text.

The Scotia Group M&A Database, January 2004
### Table D-6: Confidence Limits for Implicit Growth Rate of Natural Gas Prices

<table>
<thead>
<tr>
<th>Year</th>
<th>Implicit Annual Growth Rate in Price (g)</th>
<th>Lower Bound (V Method)</th>
<th>Upper Bound (V Method)</th>
<th>Lower Bound (Delta Method)</th>
<th>Upper Bound (Delta Method)</th>
</tr>
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<tbody>
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<tr>
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</table>

Note: A value of 0.00 implies negligible growth rates.

Sources:

(2) Implicit Annual Growth Rate in Price, Table D-3, Col 8.
(3) See text.
(4) See text.
(5) See text.
(6) See text.

The Scotia Group M&A Database, January 2004
<table>
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<tr>
<th>Year</th>
<th>Riskless Rate (1-yr TB)</th>
<th>Oil Value ($/bbl)</th>
<th>Return to Holding Oil</th>
<th>Oil Achieved Risk Premium</th>
<th>Gas Value ($/mcf)</th>
<th>Return to Holding Natural Gas</th>
<th>Natural Gas Achieved Risk Premium</th>
<th>Required Risk Premium</th>
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<td>0.940</td>
<td>0.905</td>
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Mean 0.059 0.048 -0.014 0.104 0.042 0.073
St.Dev. 0.022 0.373 0.371 0.385 0.382 0.021
St.Err. 0.005 0.083 0.083 0.086 0.085 0.005
Mn/Se 12.099 0.578 -0.163 1.206 0.493 15.622

Sources:
(2) Federal Reserve Board Historical Rates (http://www.federalreserve.gov/releases/h15/data/a/tcm1y.txt)
(3) Oil Reserve Price, Table B-2a, Col 3.
(4) Percentage Change, Col 3 (t)/Col 3 (t-1) - 1
(5) Oil Achieved Risk Premium, Col 4 - Col 2
(6) Natural Gas Reserve Price, Table B-2a, Col 5.
(7) Percentage Change, Col 8 (t)/Col 8 (t-1) - 1
(8) Natural Gas Achieved Risk Premium, Col 8 - Col 2
(9) Required Risk Premium, LTBR (http://www.federalreserve.gov/releases/h15/data/a/tcm10y.txt)
### Table D-8: Levelized Oil Wellhead Prices

<table>
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<tr>
<th>Year</th>
<th>Required Risk Premium</th>
<th><strong>R/P</strong> Ratio</th>
<th>Reserve Price $/bbl</th>
<th>Decline Rate (a)</th>
<th>Discount Rate</th>
<th>Operating Cost (c) $/bbl</th>
<th>Levelized Wellhead Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
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**Sources:**

2. Production/Reserves Ratio, P/R, Table D-1, Col 2.
3. Reserves/Initial Output Ratio, [Column (3)] ^-1.
4. Reserve Price (b), Table D-1, Col 4.
5. Adjusted Ratio (a), Table D-1, Col 3.
6. Discount Rate, 0.02*Column (2).
7. Operating Cost (c), Table D-1, Col 6.
8. Levelized Wellhead Price, {Col (4) * Col (5) * [ Col (6) + Col (7) ]} + Col (8).
### Table D-9: Levelized Gas Wellhead Prices

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<th>Year</th>
<th>Required Risk Premium</th>
<th>P/R Ratio</th>
<th>R/Q Ratio</th>
<th>Reserve Price $/bbl</th>
<th>Decline Rate (a)</th>
<th>Discount Rate</th>
<th>Operating Cost (c) $/bbl</th>
<th>Levelized Wellhead Price</th>
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**Sources:**


(3) Production/Reserves Ratio, P/R, Table D-3, Col 2.

(4) Reserves/Initial Output Ratio, [ Column (3) ] ^-1.

(5) Reserve Price (b), Table D-3, Col 4.

(6) Adjusted Ratio (a), Table D-3, Col 3.

(7) Discount Rate, 0.02*Column (2).

(8) Operating Cost (c), Table D-3, Col 6.

(9) Levelized Wellhead Price, {Col (4) * Col (5) * [ Col (6) + Col (7) ]} + Col (8).
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Sources:

(2) Levelized Oil Price, Table D-8, Col 9.
(3) Oil Field Price, Table C-4, Col 2.
(4) Ratio, Col 2 / Col 3
(5) Levelized Gas Price, Table D-9, Col 9.
(6) Gas Field Price, Table C-4, Col 5.
(7) Ratio, Col 5 / Col 6
Figure 5: Levelized Oil Wellhead Prices derived from Reserve Values and Field Prices, 1982-2003
Figure 6: Levelized Wellhead Natural Gas Prices derived from Reserve Values, and Field Prices, 1982-2003
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(2) Production/Reserves Ratio, P/R, Table C-1e.
(3) Adjusted Ratio (a), see text.
(4) Reserve Price (b), Table B-2b.
(6) Operating Cost (c), 35% of field price.
(7) Field Price (p), Table C-1a.
(8) Implicit Annual Growth Rate in Price, see text.
(9) Net Field Price, p-c, Column (7) - Column (6).
(10) HV to Reserve Price, Column (9) / Column (4).
(11) HV Spread, [Column (9) - Column (4)] / Column (5).
Table D-1a: Estimates of Hotelling Values and Price Expectations, All Oil

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(7) Field Price (p), Table C-1a.
(8) Implicit Annual Growth Rate in Price, see text.
(9) Net Field Price, p-c, Column (7) - Column (6).
(10) HV to Reserve Price, Column (9) / Column (4).
(11) HV Spread, [Column (9) - Column (4)] / Column (5).
Table D-1c: Estimates of Hotelling Values and Price Expectations, All Gas

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<td>1.74</td>
<td>4.98</td>
<td>-0.04</td>
<td>3.24</td>
<td>2.46</td>
<td>29.87</td>
</tr>
</tbody>
</table>

Sources:

(2) Production/Reserves Ratio, P/R, Table C-1e.
(3) Adjusted Ratio (a), see text.
(4) Reserve Price (b), Table B-2b.
(6) Operating Cost (c), 35% of field price.
(7) Field Price (p), Table C-1a.
(8) Implicit Annual Growth Rate in Price, see text.
(9) Net Field Price, p-c, Column (7) - Column (6).
(10) HV to Reserve Price, Column (9) / Column (4).
(11) HV Spread, [Column (9) - Column (4)] / Column (5).
Figure 1: Oil Reserve Prices for 1982-2003

- Reserve Price ($/bbl) - All Transactions
- Oil Reserve Price ($/bbl) - Without Outliers
Figure 2: Natural Gas Reserve Prices for 1982-2003

- Natural Gas Reserve Price ($/mcf) - All Transactions
- Natural Gas Reserve Price ($/mcf) - Without Outliers
Figure 8: Levelized Oil and Gas Prices
Figure 3: Estimates of Hotelling Values and Price Expectations, Oil
Figure 4: Estimates of Hotelling Values and Price Expectations, Natural Gas
Figure 5a: Implicit Annual Growth Rates for Oil Prices, All Transactions
Figure 5b: Implicit Annual Growth Rates for Natural Gas Prices, All Transactions
Figure 6: Implicit Annual Growth Rate for Oil and Natural Gas Prices, Pure Transactions
Figure 7: Returns to Holding Oil and Natural Gas Reserves

Year

Return (%)

-0.800 -0.600 -0.400 -0.200 0.000 0.200 0.400 0.600 0.800 1.000 1.200


Achieved Risk Premium for Oil
Achieved Risk Premium for Natural Gas