Analysis of Oil and Gas Exploration and Discovery in New Zealand - A Basis for Supply Forecasting

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Abstract

The long term sustainability of oil and natural gas supply in New Zealand will depend upon several factors, in particular the size and location of commercially exploitable resources, and the success of industry in locating undiscovered resources. A growing body of geological research supports a good case for the likely occurrence of oil and gas in several sedimentary basins, and exploration effort (primarily directed at finding oil) has increased from the very low levels of the early 1990s.

This research analyses the record of exploration and discovery in New Zealand since 1970 to provide answers to three questions: What is the level of reward obtained from investment in oil exploration? Given the reward for effort relationship what level of exploration investment will be required to provide reasonable assurance of new discoveries of a magnitude to maintain New Zealand's current petroleum self sufficiency level? What factors determine the levels of exploration investment in New Zealand?

A simple recursive modelling approach is used to establish answers to the three questions. Using data for the period 1970-93, a reward for effort relationship is estimated at 0.92 MMBOE per kilometre drilled. This figure is remarkably close to the value 0.90 calculated by Cook (1985) using cumulative 1950-85 data. Given current New Zealand oil and gas reserves, petroleum usage growing at 1.6% per annum, and the calculated reward for effort relationship, the level of exploration required to maintain New Zealand's current level of petroleum self sufficiency is estimated at 40 wells per year. At current drilling costs, the exploration programme will require annual investment between $240 million (onshore) and $800 million (offshore).

Six variables were hypothesised as determinants of oil and gas exploration effort, and 1970-93 time series data was used to test these relationships. The cost of drilling, world oil price, and New Zealand petroleum demand were found to be statistically significant explanations for exploration effort. Government policy appears to be only weakly related to exploration effort. Variations in oil price, drilling costs, and petroleum demand, are introduced to determine their possible effects on future exploration effort, and from this some policy conclusions are drawn.

Introduction

Oil and gas exploration activities in New Zealand date back to as early as the 1860s. Exploration activities until the 1950s were associated with natural oil and gas seeps and had few encouraging results. Sophisticated search techniques introduced in the 1950s led to the discovery of large reservoirs thus turning a new page in the history of petroleum exploration. Since then exploration activities have been carried out in many basins of both islands, but significant finds have been made only in the Taranaki Basin. Therefore exploration activities have concentrated on the Taranaki Basin, while the exploration effort on other basins diminished (Ministry of Commerce 1991, Beggs and Cook 1993).

Total primary energy supply in New Zealand is projected to grow at 1.6% per annum between 1995 and 2020, from 591 to 874 PJ pa. Gas consumption is projected to peak in the year 2000, at 208 PJ pa, and then decline to around 98 PJ pa in 2020, resulting in an average decline in consumption of 2.4% pa between 1995 and 2020. However, the primary energy demand for oil is projected to grow strongly at 2.5% pa from around 212 PJ pa in 1995, to around 338 PJ pa in 2020 (Ministry of Commerce 1997a). Current oil reserves were 778.2 PJ as at January 1996. Oil production in 1995 and 1996 was 68.32 PJ and 69 PJ respectively. If we assume that this production level is to be maintained for the coming years without augmentation by production from newly developed fields, the remaining oil reserves will supplement national oil demand until 2006. Latest available information indicates the current level of oil and gas production within New Zealand will fall and the discovered reserves will be totally depleted by 2006. Therefore it is obvious that unless new discoveries are made, the contribution of local production to the total oil and gas supply in New Zealand will soon fall sharply. New discoveries are important for two reasons, first to maintain the current level of domestic production and second to increase the level of self-sufficiency which reached 50% by the year 1990 but declined to 36% by 1996. The rationale for increasing the level of self-sufficiency is to reduce the burden on the New Zealand economy caused by imports of oil (Ministry of Commerce 1997a).

However, recent studies have noted a downward trend in exploration activities, the reasons for which have yet to be determined (Ministry of Commerce 1988, Ministry of Commerce 1994). In order to decide on the level of exploration needed for future supply, knowledge on topics such as the historic level of reward for effort in oil and gas exploration in New Zealand, threshold level of exploration needed to keep supply in line with the projected demand, level of investment needed to achieve that target, the factors determining the exploration activities and reasons for the decreasing trend of exploration activities in the recent past, will be of prime importance. Therefore this study was carried out aimed at achieving the following objectives.

Objectives

There are three primary and two secondary objectives of the study. The primary objectives are i) to develop a "Reward for Effort" model for Oil and Gas Exploration in New Zealand, ii) to determine the threshold level of exploration needed to meet the future supply and iii) to estimate the level of investment needed to achieve the above supply target. The secondary objectives are i) to determine the factors affecting exploration activities in New Zealand, ii) to discover the reasons for the downward trend of exploration activities in the recent past.

Methodology

Development of a "Reward for Effort" model is the key objective of this study and is followed by analysis to identify the determinants of exploration activities. Literature in support of reward for effort models for exploration in New Zealand were found in only a few places throughout the literature survey. That is an indication of the need for this kind of analysis for the benefit of the exploration industry in New Zealand. Differing terminology and definitions are used in the literature but the focus is on reward for effort in exploration.

An often quoted gauge of exploratory success is given by the number of wild cat wells required to find one significant discovery. According to the international comparisons, New Zealand's ratio is about normal ie 1:10.3 (Cook 1985). Cook (1985) has also calculated the rate of discovery by comparing cumulative reserves with the cumulative exploration effort (ie number of kilometres drilled) for the period 1950-85. According to his calculation the rate of discovery is on average 0.9 MMBOE for every kilometre drilled. The major discoveries at Kapuni and Maui fields were excluded from the analysis.

Beggs (1996) expresses "Reward for Effort" as reserves discovered per wildcat well. (The units for this ratio are millions of barrels of oil equivalent per wildcat. Gas has been converted to this measure on the basis of 5.25 billion cubic feet equals one million barrels of oil). According to Beggs, "Reward for Effort" has declined over time. The early discovery of Kapuni Field established an unsustainable factor of about 50 (19.2[1]), dropping to about 5-10 (1.9-3.8[2]) through the 1980s to a recent level of 1-2 (0.4-0.8[3]). Based on the current work programmes, between 5-10 wildcat wells are expected per year over the next five years. Applying a "Reward for Effort" factor of 1.6 to a portfolio of 25 wildcats, discovery of some 40 million barrels of oil equivalent is projected. As gas, this would amount to perhaps 100 PJ (Beggs 1996).

Ivanhoe (1986) has developed a discovery index (DI) as a proxy to the reward for effort ratio. He defined it as "annual barrels of new recoverable reserves added per foot of exploratory drilling". He used this to measure the technical effectiveness of oil exploration (new recoverable oil per unit of exploratory effort) and general oil richness of a country. He categorised different levels of discoveries as stupendous (>10000), excellent (1000-10000), good (100-1000), fair (10-100), and poor (1-10). This rate for the United States in 1982 was 19 b/ft and approaching 10 b/ft.

"Reward for Effort" in the present analysis is defined as reserves discovered per kilometre drilled. Here it is planned to estimate the reserves added for each kilometre drilled, and will facilitate calculating the gain for each dollar spent on exploration. Data on number of kilometres drilled, and the amount of reserves discovered each year will be used in the analysis. Although it is desirable to consider three different levels of resource discovery, ie hydrocarbon shows, sub-commercial finds, and commercial finds, non-availability of data for these breakdowns is a barrier to such detailed analysis. Several models from these variables are developed to establish the possible relationships between reward and effort. The most important relationship is with the commercial finds and the results of this section are used in the analyses in the subsequent sections.

The amount of reserves discovered (R) is considered as a function of the effort (E) made in drilling activities, ie R = _ (E) as, for example, in the following linear model:

$R = w E$ .... (1)

There is no intercept in the model because there is no commercial discovery without any effort in exploration[4]. The outcome of the analysis of this model will be used to determine the threshold level of exploration effort and investment needed to achieve the stipulated level of supply to meet the demand for oil and gas over the next decade.

The Level of Exploration Effort and Investment Per Annum

The level of exploration effort needed to meet the required supply from domestic sources will be estimated using the model outlined in the previous section. This will help in calculation of the minimum number of exploration wells needed to be drilled per annum to achieve 100% self-sufficiency and to maintain the current level of self-sufficiency in liquid fuels ie. 36%. The dollar investment needed for the exploration effort per annum will be calculated using average drilling costs as available from overseas databases. The calculation procedure can be described as follows.

The following equation will be used to calculate the demand for oil in the year concerned.

$D_t = D_p(1+ r)^t$ .... (2)

D_t = demand for oil in year `t'

D_p = demand for oil at present

r = rate of growth in oil demand each year

If the Reward for Effort factor from the analyses is considered as `w' , then,

The number of kilometres needed to be drilled to discover

$D_t = D_t/w$

If the average depth of a well is `h' km, then,

The number of wells needed to be drilled per year =

$(D_t/w) \times 1/h$

If the average investment for a well is NZ$ `m', and the desired self-sufficiency level is `s', then the annual level of investment for exploration activities to meet `s';

= NZ$ (D/w) x m/h x s

where $0 < s < 1.0$

Determinants of Exploration Activities

Possible reasons for the downward trend in exploration activities were extracted from literature as well as from personal communications with experts. The findings of this survey were used to define the variables and they are statistically tested using the following method. Variables identified with data available are explained below. Multiple Regression Analysis (Maddala 1989) will be used in determining the factors influencing oil and gas exploration activities. Here the rate of exploration (E) is hypothesised to be a function of the identified variables explained below (X_1 to X_6).

$E = \_ (X_1, X_2, X_3, X_4, X_5, X_6)$ .... (3)

Dependent variable:

E = rate of exploration (number of kilometres drilled per year)

Independent variables:

X_1 = average drilling cost per kilometre (US$)

X_2 = discovery rate (amount of reserves discovered per kilometre per year)

X_3 = world oil prices (US$)

X_4 = demand for oil in New Zealand (PJ per year)

X_5 = level of geological knowledge available (amount of 2D seismic data in kilometres)

X_6 = government policy (a dummy variable to represent encouraging and discouraging policy regimes)

Variable X_2 will use lagged data while all others including E use current year data. The model can be depicted as a linear equation as shown below where b_0-b_6 are parameters to be estimated.

$E = b_0 - b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6$ ...... (4)

More parsimonious models on the basis of subsets of the variables will be tried and the most data consistent model will be selected following a "general to specific" modelling strategy as discussed in the next section. Different scenarios based on the independent variables of the selected model will be also tested to forecast E and R values.

Data

The study is mainly based on a data base developed by the Institute of Geological and Nuclear Sciences Limited (IGNS), Lower Hutt, New Zealand (IGNS 1997). However, due to gaps in the data base and the non availability of some variables included in the proposed analyses, other sources were used to provide required data for econometric analysis. The other data sources came from the relevant literature, databases of Statistics New Zealand (1976, 1996, 1997), the Ministry of Commerce (1992a, 1993b, 1997a and c) and United States data bases (AER 1997, IPAA 1997) from the Internet.

Results and Discussion

Reward for Effort Model

Two variables were considered in the analysis to develop a Reward for Effort model. Simple regression analysis was used for this purpose. Total reserves discovered each year in MMBOE was the dependent variable which was considered as the `Reward' (R) and total kilometres drilled each year was the independent variable which was considered as the `Effort' (E) in petroleum exploration. Although the original data set comprises annual time series for the period 1959 through 1997, the analyses carried out in this paper uses observations for the 1970-93 period due to unrecoverable gaps in the data set.

Cook (1985) calculated the rate of discovery as 0.9 MMBOE for every kilometre drilled and this figure provides some support for the Reward for Effort model that is derived in the current analysis. Cook's analysis covers the period 1950-85 and used cumulative reward and effort values. For purpose of comparison, a regression model $R_t = b * E_t$ was estimated for the 1970-93 period where R_t and E_t are cumulative values of reward and effort respectively as in the earlier Cook study. The regression equation that is named the Cook model is as follows.

Cook Model: $R_t = 1.04\ E_t$ .... (5) (29.27)

The coefficient of this model is the "Reward for Effort factor" (1.04) and it approximately equals Cook's original value of 0.9 which he defined as the discovery rate. The model is statistically highly significant due to the nature of the cumulative time series approach (t value in parentheses).

This analysis was done for comparison purposes and to link the present analysis to the previous work. Cook's (1985) relationship matches the figure in the model above and both use cumulative data, although they study different time periods. The largest discoveries in the recent past, ie Kapuni (1959) and Maui (1969) fields, were in the period Cook studied but they have been excluded from his analysis as he considered them to be outliers. Excluding those cases, there have been no other outstanding discoveries between 1950 and 1985 to influence the coefficient. This is the reason the reward for effort coefficient for the period 1970-93 which has been calculated in the present analysis, is so close to Cook's coefficient.

The next step was to use regression analysis but without using cumulative figures. Although there were no discoveries for some years, 24 observations continuously from 1970-93 were used in the analysis. The results are presented in the following equation as the Lincoln model.

Lincoln Model: R = 0.92 E .... (6) (2.51)

According to the t-statistic (2.51), the coefficient of the Lincoln Model is statistically significant and is approximately equal to the reward effort factor in the Cook model. Further, the residuals were tested for possible autocorrelation. The estimated _ value which is close to zero (_ = - 0.16704) indicates that there is no autocorrelation problem. In addition, a Dubin-Watson test was carried out to confirm the above result. The DW statistic is 2.29. According to the DW tables of Farebrother (1980), for serial correlation when there is no interception in the regression, the corresponding DW value is 2.57 (DW 95% minimal bound, k-0, N=24). This result confirms the previous result for absence of serial correlation in the residuals and confirmed the validity of the results of the Lincoln Model. Therefore, the Lincoln Model is accepted as the "Reward for Effort model" in this analysis and hence the "Reward for Effort factor" is 0.92. This means there has been a discovery of 0.92 MMBOE for every kilometre drilled during the period concerned in the analysis. This figure is used below to calculate the exploration effort needed to meet future demand.

The Level of Exploration Effort and Investment Per Annum

This section presents the calculations to determine the level of exploration effort and the investment needed to meet oil and gas demand in 2010, using the reward for effort factor from the Lincoln Model.

D_t = demand for oil in the year `t' = 15 - in 2010,

D_p = demand for oil at present = 386.7 PJ in 1995

r = rate of growth in oil demand each year = 1.6 %

If the Reward for Effort factor from the analyses is considered as `w= 0.92', then,

$D_t = D_p(1+ r)^t$ .... (2)

Demand in 2010, $D_{2010} = 386.7(1+0.016)^{15}$ = 490.7 PJ = 85.8 MMBOE

(5.72 PJ = 1 MMBOE)

The number of kilometres needed to be drilled to discover the amount demanded in 2010;

= D_{2010}/w = 85.8/0.92 = 93.3 km

The average depth of a well is `h=2.6 km'

Therefore, the number of wells needed to meet demand in 2010;

= $(D_{2010}/w) \times 1/h$ = 93.3/2.6 = 35.9

This figure represents 100% self-sufficiency and assumes that the past reward for effort relationship will be maintained. It is also assumed that all current reserves will be exhausted by the year 2010. According to the above results, to ensure the discoveries fully meet the oil and gas demand anticipated in 2010 or to achieve full self sufficiency by 2010, around 36 (35.9) wells per year must be drilled by the year 2000 because there is a 7-10 year lead period for development of the wells before they are ready for production. This seems to be a high target to achieve. An alternative goal is considered - maintaining the present level of self-sufficiency. The present level of self-sufficiency in liquid fuels is 36%. Therefore, to maintain 36% self-sufficiency in 2010, at least 13 (12.92) wells need to be drilled each year from 2000 onwards.

The number of wells needed to maintain the current level of self-sufficiency (36%) in 2010;

= 35.9 x 0.36 = 12.92

To calculate the dollar investment needed to achieve this target, the following cost figures (PEANZ 1994) are used.

A work programme to drill a single offshore well

= NZ$20 million

A work programme to drill a single onshore well

= NZ$6 million

To achieve the supply target for 2010;

Investment needed for 13 offshore wells a year

= NZ$20 x 13 = NZ$260 million/year

Investment needed for 13 onshore wells a year

= NZ$6 x 13 = NZ$78 million/year

There is no adequate data to determine the likely proportion of onshore to offshore wells. According to the literature, best prospects are in the offshore area. But there are good onshore prospects in new basins outside Taranaki. The above calculations are summarised for 100% and 36% self-sufficiency respectively in Table 1 and 2, including calculations for 1995 and 2000 for comparison.

Year	Demand (MMBOE)	Number of wells	Inv3[5] -Onshore	Inv3 -Offshore
1995	67.6	28.3	169.8	566

2000	73.2	30.6	183.6	612
2010	85.8	35.9	215.4	718

Table 1. Investment and exploration effort need to discover oil (100% self-sufficiency).

Year	Demand (MMBOE)	Number of wells	Inv3 -Onshore	Inv3 -Offshore
1995	24.3	10.2	61.1	204
2000	26.4	11.0	66.1	220
2010	30.9	12.9	77.5	258

Table 2. Investment and exploration effort need to discover oil (36% self-sufficiency).

Determinants of Exploration Activities

This analysis was aimed at finding factors affecting exploration activities in New Zealand. Multiple regression analysis was performed for this purpose. Rate of exploration is defined as the number of kilometres drilled per year and is considered as the dependent variable (E), and the other six variables defined above were used as independent variables. Restricted models were developed in the process by deleting variables with statistically insignificant coefficients. The ultimate restricted model has only three variables with statistically significant coefficients. The model is as follows;

$$E = -2.25 - 0.00029\ X_1 + 1.85\ X_3 + 0.2\ X_4 \ .... \ (7)\ (2.21)\ (2.01)\ (3.32)$$

According to this model world oil prices and the demand for oil within New Zealand are positive influences on the exploration activities in New Zealand while cost of drilling has a negative effect on exploration. Government policy X_6, also showed some evidence of influence on exploration at high levels of statistical significance.

Scenario Testing to Project Reward and Effort for the Next Decade

Scenarios were developed and tested to project the values for E in the above model. Two demand scenarios were considered for years 2000 and 2010. Values for demand were calculated with the compound growth formulae, using 1995 consumer demand for oil (386.7 PJ) as the base value. Corresponding values for 2000 and 2010 are 418.6 PJ and 490.7 PJ respectively. Three cost scenarios based on the average cost of drilling and three price scenarios based on the average world oil price for 1986-1995 period were developed.

Cost Scenarios

1. Average cost (1986-95) = 223914.6 US$
2. Average cost - Standard deviation for 1986-95 (18304) = 205610.6
3. Average cost + Standard deviation for 1986-95 (18304) = 242218.6

Price Scenarios

1. Average price (1986-95) = 17.9 US$
2. Average price - Standard deviation for 1986-95 (4.7) = 13.2
3. Average price + Standard deviation for 1986-95 (4.7) = 22.6

Altogether there are nine scenarios ie AD, AE, AF, BD, BE, BF, CD, CE, CF. These nine scenarios were tested for years 2000 and 2010. The results are presented in the Table 3. To achieve 36% (current level) self-sufficiency in oil in 2000 and 2010, 26.4 and 30.9 MMBOE of oil reserves must be discovered according to the calculations (Table 3). All scenarios for year 2000 provide reward figures higher than 26.4 while all scenarios for 2010 also provide figures higher than 30.9. The scenario with the highest drilling cost and the lowest oil price (CE_{2000} and CE_{2010}) provides a higher number of wells than needed to meet 36% self-sufficiency level. Required number of wells for 2000 is 11 but CE_{2000} effort value is about 15 wells (38.1/2.6 = 14.7). The required number of wells for 2010 is 13 but CE_{2010} effort value is about 20 wells (52.8/2.6 = 20.3). This suggests that if the current trend in exploration continues over the next decade, there is a possibility of maintaining the current level of self sufficiency provided other variables remain within the expected ranges.

Scenario	Year	E	Std Er[6]	(U)CI[7]	(L)CI[8]	X1	X3	X4	R

AE_{2000}	2000	43.39	16.37	59.76	27.02	223914.6	13.2	418.6	39.7
AD_{2000}	2000	52.07	16.07	68.14	36.00	223914.6	17.9	418.6	47.7
AF_{2000}	2000	60.75	16.54	77.29	44.21	223914.6	22.6	418.6	55.6
BE_{2000}	2000	48.64	16.37	65.00	32.27	205610.6	13.2	418.6	44.5
BD_{2000}	2000	57.32	16.58	73.89	40.74	205610.6	17.9	418.6	52.5
BF_{2000}	2000	66.00	17.51	83.51	48.49	205610.6	22.6	418.6	60.4
CE_{2000}	2000	38.14	16.79	54.93	21.36	242218.6	13.2	418.6	34.9
CD_{2000}	2000	46.82	15.99	62.81	30.84	242218.6	17.9	418.6	42.8
CF_{2000}	2000	55.50	15.94	71.44	39.56	242218.6	22.6	418.6	50.8
AE_{2010}	2010	58.12	17.99	76.10	40.13	223914.6	13.2	490.7	53.2
AD_{2010}	2010	66.80	18.19	84.99	48.61	223914.6	17.9	490.7	61.1
AF_{2010}	2010	75.48	19.06	94.53	56.42	223914.6	22.6	490.7	69.1
BE_{2010}	2010	63.37	18.46	81.82	44.91	205610.6	13.2	490.7	58.0
BD_{2010}	2010	72.04	19.09	91.14	52.95	205610.6	17.9	490.7	65.9
BF_{2010}	2010	80.72	20.33	101.06	60.39	205610.6	22.6	490.7	73.9
CE_{2010}	2010	52.87	17.89	70.76	34.98	242218.6	13.2	490.7	48.4
CD_{2010}	2010	61.55	17.63	79.18	43.92	242218.6	17.9	490.7	56.3
CF_{2010}	2010	70.23	18.07	88.29	52.16	242218.6	22.6	490.7	64.3

Table 3. Forecasted values for Reward and Effort according to the defined scenarios.

Reasons or a Downward Trend in Exploration

Apart from the empirical analysis, literature review discloses some reasons behind the downward trend in exploration activities in the recent past. A period of uncertainty concerning the New Zealand investment regime, low oil prices and fierce competition worldwide for internationally mobile exploration funds resulted in a significant decline in petroleum exploration in the early 1990s (Statistics New Zealand 1997). International oil price movements and political developments and the developments in the New Zealand's economy and energy markets in particular have had major impact on this situation. Political and fiscal factors in the late 1980s combined with a plethora of new, large opportunities overseas to draw exploration investment away from New Zealand even as its geological potential became more widely acknowledged (Beggs 1997).

Due to the tax system, royalties and lack of incentives under take or pay contracts, companies had little or no incentives to expand gas reserves (Beggs 1997). Government responded with rationalisation of legislation (the Crown Minerals Act 1991) and the allocation process. A sustained downturn in oil and gas exploration in New Zealand which set in about 1989 was reversed in 1995-96 with some important wildcat wells being drilled and a reasonably robust upturn in new permit allocations. A new royalty system and permit allocation regime as of January 1996 was able to attract new exploration investment (Statistics New Zealand 1997).

The complexity of New Zealand geology impedes exploration by contributing to uncertainty and New Zealand's geographic location also has a considerable impact via cost and lags in getting drilling rigs here. New Zealand is remote from major exploration services and supply bases making both seismic and drilling programs expensive and logistically challenging. Weather and sea conditions are unpredictable and frequently severe. Most of these factors have to be considered in analyses of likely costs and payoff from exploration investment (Beggs 1997).

Conclusions

The outcome of the first phase of the analysis provides a reward-effort factor of 0.92 which means a discovery of 0.92 MMBOE of crude oil per each kilometre drilled during the 1970-93 period. This figure exactly matches the discovery rate calculated by Cook (1985) a decade ago. For comparison purposes, an analysis was completed using cumulative data for a period of 24 years from 1970-93, and calculated a very similar reward for effort coefficient of 1.04. Non-cumulative data used for the present analysis provide a similar factor which confirms the general discovery rate for the New Zealand oil exploration industry. Analysis by Beggs (1996) also shows a similar figure (0.8 - see the first paragraph of page three) for the period after the 1980s. Apart from the major Kapuni and Maui fields, all other discoveries are at modest scale throughout the past half century. If the reward effort factor of 0.92 is considered, on average 13 wells should be drilled a year from year 2000 onwards to maintain the current level of 36% self-sufficiency by the year 2010. To achieve this target, NZ$78-260 million investment per year will be required on exploration wells.

Although there are many factors influencing exploration activity in New Zealand, six factors were included in the second part of the analyses to statistically test their influence. The analysis shows that only three factors are statistically significant. Cost of drilling has a negative effect on exploration activity while world oil prices and the demand for oil within New Zealand are positive influences. The dummy variable used to represent the effect of government policy on exploration suggests this factor had some influence on exploration rate. But it was not included in the final model because the level of significance is too low to justify retaining the variable in the model. There is ample evidence from the literature showing positive effects of the change in the government policy in favour of the exploration industry, which tremendously increased exploration in different basins in different time periods. The exact effect of the policy changes may not have been accurately represented by the dummy variable which in turn may explain its insignificant contribution to the model. However, the effect of this variable cannot be ignored and should be considered in further analysis with an improved database. However, the scenario testing provides evidence of the strong likelihood of maintaining the current level of self-sufficiency for the next decade, if the price and cost fluctuations of the past 10 years remain in the same range.

Apart from the statistical analyses, other reasons for the downward trend in exploration activities in the recent past can be proposed. They include: uncertainty in the New Zealand investment regime; competition worldwide for internationally mobile exploration funds; international political developments; better opportunities overseas; tax system; royalties; developments in the New Zealand economy and energy markets; complexity of New Zealand geology; geographical location of New Zealand which is remote from major exploration services and supply bases making both seismic and drilling expensive and unpredictable; and frequently changing sea and weather conditions. All these factors should be considered in more comprehensive future analyses to draw more realistic conclusions.

Limitations of the Study

Gaps in the data set compelled reduction in the time period considered in the analysis to only 24 years. Graphical presentations of the data for extended periods exist in the literature, but it did not prove possible to obtain the data which provide the basis for those presentations. Because New Zealand data is not available, or not within our reach due to difficulty in access, United States data were used as a proxy for some variables used in the analyses such as cost of drilling. Access to and analysis of more comprehensive and recent data will be invaluable in enhancing the quality and the validity of future studies in this area. Data for the years post 1993, will be particularly useful in forecasting expected levels of exploration.

Policy Implications

The analyses do not show a great impact of government policies on exploration activity. Although this variable is not statistically significant at a high level, its effect should not be neglected or ignored. Its importance is frequently mentioned throughout the literature and the positive impact of favourable government policy on exploration rate is noted by observers. The negative effect of increased drilling cost on exploration activities is confirmed by the analyses. At the same, world oil prices show a positive effect on exploration rate. The New Zealand government can consider how its actions might influence the exploration rate when formulating policies to ensure domestic oil and gas supplies are maintained. Availability of information on the petroleum potential in New Zealand, simplicity and transparency of information on allocation and royalty regimes, and barriers to exploration on land could all be reviewed to improve the attractiveness of New Zealand for exploration investment.

Further Research

Compared to the geological and engineering knowledge available on this subject, knowledge on petroleum economics is limited. The New Zealand petroleum exploration situation is very different compared to the situation in many other countries. No earlier attempt at economic analysis of petroleum exploration activities in New Zealand has been discovered. The topics that have been covered in this study can be enhanced in future studies with more comprehensive data bases. Research literature repeatedly shows the importance of government policy in enhancing exploration activity but the crudeness of the variable used in this analysis probably reduces the likelihood of a statistically significant impact of government policy on exploration activities. Equally the variable used for level of geological knowledge is extremely crude. Developing the data base to include more data, and more accurate variables, should be a high priority for future researchers.

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Footnotes

1. MMBOE/km within parenthesis.
2. Ibid
3. Ibid
4. Unlike early stages of oil discovery where natural oil seeps were available to extract oil.
5. Investment in million dollars.
6. Standard error of forecasted E
7. Upper limit of the confidence interval of forecasted E.
8. Lower limit of the confidence interval of forecasted E.

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