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Robustness of Firm-Specific and Macroeconomic Determinants of Exploration Investments Implications from Egyptian Oil & Gas Industry

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Robustness of firm-specific and macroeconomic determinants of exploration investments

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Abstract

Purpose – The uncertainty that surrounds oil and gas exploration environments call for an examination at different angles. In terms of robustness, the purpose of this paper is to focus on three performance measurements: the amount of exploration investments, the growth rate of exploration investments, and the value at risk (VaR) of exploration investments.

Design/methodology/approach – The study utilizes the properties of discriminant analysis for deriving *Z*-score models that can be used for monitoring firms' performance. A cointegration analysis is utilized as well in order to examine the level of cointegration between predictors of each performance measure. The sample includes annual data for 41 firms (local and multinational) working in the oil and gas industry in Egypt for the period 2009-2014.

Findings – The results show that amount and growth of exploration investment are quite robust performance measures in the oil and gas industry; VaR of exploration investment is sporadic as it firm-specific; and GDP, capital expenditure and operating expenditure are quite relevant for managing and monitoring growth of exploration investments.

Originality/value – The study offers robust evidence that amount and growth of exploration investment are quiet relevant for measuring firm performance in the oil and gas industry.

Keywords Cointegration analysis, Egypt, Johansen cointegration, Discriminant analysis, Oil and gas exploration investments, Performance measures- growth rates – VaR, International oil companies (IOCs)

Paper type Research paper

Introduction

Oil can be considered as the cornerstone of modern society, considering its role in providing affordable energy to energize production processes, fuel the global economy, provide income to producers, and support everyday life. However, the uneven distribution of oil resources, fast exhaustion of oil, depletion of existing oil fields as well as the progressive

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reduction in size of discoveries threaten the global oil supply balance and energy security. More profound is the fact that the demand for oil is rising and exploration investment declining. It is therefore pertinent to investigate the drivers of exploration investment.

Maximizing social benefits through the exploitation of petroleum resources seems to be the primary objective of host governments (Tordo, 2010). Consequently, the fiscal terms and sharing mechanisms at the exploration phase compound the uncertainties of investment decisions. Several studies have analyzed the influence of various factors (economic, policy/institutional, technological, and geological) in driving the exploration investment decisions in various petroleum-rich jurisdictions.

However, less attention has been paid to the oil and gas investment behavior in developing countries due to lack of data. Similarly, very few empirical studies consider the drivers of exploration investment, although these studies do not examine below-ground uncertainties. At the exploration phase, below-ground factors play a critical role in investment decisions, because the success of a venture depends largely on the below-ground unknowns. Even when oil prices are high, non-promising geological conditions may lead to delays, suspensions of exploration, or complete change of investment plans. Although Michot (2000) states that oil prices constitute one of the "fulcrums of exploration industry's decision making," Hvozdyk and Blackman (2010), Pirog (2012) and Hazarika (2015) conclude that oil prices do not significantly impact the profitability, liquidity, efficiency, and financial health of top oil and gas companies. The current study also seeks to investigate the relationship between oil prices, production, and exploration investment by considering their strategic importance in defining the cash-flow profile and rate of return on investment.

Given the high economic stakes, government interventions in the industry are wide spreading which creates potentials for wrestling over investment returns with international oil corporations (IOCs). Moreover, the high economic stakes and weak market fundamental due to the mounting energy subsidy representing huge challenges for the IOCs to invest in Egypt to meet the rapidly increasing demand. As the Egyptian Government subsidies keep domestic gas prices too low, coupled with the increase in political risk, IOCs must consider comprehensive measures of exploration investments. Consequently, the examination of the firm-level and country-level determinants of the oil and gas exploration investment in Egypt could encourage the regulators to make informative decisions. This study examines three distinct performance measures that are oil and gas industry specific. The first measure is growth of exploration investment. The second is the value at risk (VaR) for exploration investments. The amount of exploration investment carries certain importance to the company as far as its financing resources are considered. The growth rate of exploration investments carries other implications to the company as well as to the country. In this case, the growth rate is a critical factor that determines the future of the business. The amount of exploration costs that might be lost (VaR) carries critical further implications regarding the worthiness of the investment in a certain country.

Objectives of the study

This study aims at fulfilling the objectives that follow:

(1) examine the firm-level and country-level determinants of oil and gas exploration investments in terms of amounts, growth rates and VaR; and

(2) examine the relative importance of the firm-level and country-level determinants of exploration investments in terms of amounts, growth rates and VaR.

Contribution of the study

The study contributes to the related literature in terms of:

(1) developing models that can be used for monitoring the relevant aspect of firm performance in the oil and gas industry; and

(2) measuring the firm performance in terms of growth and risk elements which matter to the nature of the industry's operations.

The rest of the study is organized as follows. The first section discusses the strategic factors that must be considered when making oil and gas investment decisions. The second section discusses risk management in oil and gas industry. The third section discusses the nature of exploration investments in the oil and gas industry. The fourth section offers an overview about the Egyptian oil and gas industry. The fifth section discusses the data, statistical test, estimation methods and an analysis of the results. The sixth section concludes.

Strategic factors in oil and gas investment decision making

The selection of the right oil and gas upstream or downstream investments ensures IOCs' growth and success, a comprehensive evaluation of exploration and production prospects in the oil and gas industry is becoming increasingly crucial to commercial success especially in today's climate of risk and uncertainty. Nowadays, most of the oil and gas big discoveries are located in hostile environments where risks are higher and costs are massive. Therefore it is vital to run a complete and integrated assessment from the early identification phase of a project. The complex geological models and reservoir interpretation data shall be converted into the realistic production profiles and cost effective development options essential to the business decision process (HM Treasury, 2014). Together with economic assessment and risk management strategies, these factors have a big influence on successful managerial and investment decisions.

The oil and gas upstream investments depends on the politics and history of each host country, the size of its hydrocarbon resources, and its overall economic situation (Khadduri, 2002; Nouara, 2015). For a foreign investor, this takes a high importance in case of new country entry, a key determinant of access to below-ground resources is how well it can meet this challenge (Zanoyan, 2002). However, most developing governments still tend to view foreign investor's presence in their country with a degree of resentment which can make the entry process very challenging, preventing many investment opportunities from going beyond the initial conceptual phase. In general, governments in a host country and foreign investors, which are mostly IOCs, have different views regarding upstream development. The main objective of the IOC is profit maximization, while the government is interested in maximizing the economic values of its natural resources.

Conflicting views lead to renegotiation of contracts and less efficient running of the business. IOCs are constantly concerned with time and the expeditiousness of contracts and projects; however, time is rarely considered in commercial negotiations for most governments. While IOCs are aware that they are in competition and are forced by the market to improve their competitive positions, governments often fail to make the most of their competitive potential due to other conflicting priorities that governments often face, and in part due to a general lack of realization that even sovereign states need to be competitive (Zanoyan, 2002). It is important to point out that all players in the global upstream business face specific market conditions and specific competitive challenges. Governments and IOCs, although technically and operationally in the same industry and in the same market, do face considerably different issues and concerns (Pongsiri, 2004). Each side sees some of the issues facing the other side only when these become directly exposed in their bilateral relationship. IOCs compete for opportunities to access the below-ground resources, and governments compete for foreign investment and enhanced value such as management skills and transferred technology. Their relationship is critical in facilitating or hindering investment. If the relationship is tense and mistrust exists due to commercial or cultural conflicts, investments do not happen. On the other hand, if both can see how their interests are aligned and understand how each side can benefit from the other side, projects acquire a new momentum and investments happen (Zanoyan, 2002). For some countries, the government and IOCs have fully realized the virtue of establishing a partnership. Hence, governments may want to facilitate more business cooperation between the existing concessionaires and the new international investors. From the concessionaires' perspective, business collaboration is driven by economic incentives or economy of scale (Pongsiri, 2004).

Pongsiri (2004) argues that upstream investment criteria for the IOCs are different in terms of their size and competitive advantage. These criteria would bring in different considerations in targeting "quality" assets. These include growth potential, materiality, commerciality, corporate goals, quality and diversity of asset portfolios, and contribution to economies of scale and other synergies. These considerations imply that the same asset may represent different value to different companies, which, in turn, leads to considerable variation in how various IOCs bid for the same opportunity. This also contributes to shaping the relative competitive positioning of IOCs in a given country, and thus gives the host government an opportunity to assess and evaluate the overall merit of each foreign investor (Zanoyan, 2002). In general, IOCs will diversify and prioritize their portfolios to invest in the potential markets that can provide them the highest commercial return. Therefore, investment capital and human resources must be effectively utilized to maximize the return. Countries wishing to attract and foster upstream investment need to understand that they compete for those investments globally on the basis of complicated risk-reward analysis, and that their policies, institutions, and regulations affect their desirability as an investment location (Smith, 2002).

Risk management in oil and gas industry

The term risk has largely negative connotations for most people. As a result, risk management is often seen as means of controlling negative outcomes rather than managing the full spectrum of uncertainty, including potential upsides and opportunities. In order to overcome this, the term uncertainty is sometimes preferred to risk. In this regard, decisions to invest in the development of oil fields are always taken under conditions of uncertainty. The performance that may be expected of reservoirs is uncertain, as is the economic climate in which investment decisions are made and the resulting projects operated (Stevens, 2008). The expected reservoir performance is uncertain because the properties of the reservoir can never fully be defined at the point in time at which an investment decision is made. The cost of constructing and operating wells and production facilities is also uncertain, primarily because the design and use of these elements is directly a function of the performance of the reservoir (Bilderbeck and Beck, 2005).

Impact and probability are cross-referenced in order to identify the overall severity of the risk. Each risk is also analyzed in terms of "manageability versus severity." A subset of the risks can also go through a quantitative analysis. In this case, a numeric estimate of both the impact of the risk on the project and probability of occurrence need to be provided. Risk response plans are also developed. Such plans can include "mitigation" actions, "transfer/share" actions, avoidance" actions and "acceptance" of the risk, with a contingency budget to be used if the risk occurs.

Exploration investments in the oil and gas industry

Reiss (1990) examines the financial determinants of exploration investments. He finds that financial factors such as cash flow and current maturities of long-term debt explained some variation in investment spending. He also concludes that the use of oil and gas reserves as collateral was seen to have potentially important implications for how much firms could borrow during deflationary periods.

Iledare and Pulsipher (1999) specify the oil drilling equation for the US Gulf of Mexico Outer Continental Shelf region. They investigate the effect of net operating profit, success rate, the technical progress proxy by the cumulative reserves discovered, as well as the changing oil market conditions and institutional changes on the finding rate of oil. They find a statistically significant positive effect of net unit operating profit and success rate on the finding rate. Their results show a negative effect of resource depletion, institutional changes, and market conditions on the finding rate. In the same manner, Farzin (2001) specifies an econometric model for additions to the US proven reserves. He tested the effects of technological progress, expected resource prices, and cumulative reserves development on reserve additions. He further found strong statistical evidence for a significant effect of explanatory variables on additions to the US proven reserves, and the estimated price elasticity reveals a small effect to the order of 1.5-4.5 percent.

Managi *et al.* (2005) estimated an oil exploration-discovery behavior model for the Gulf of Mexico. They apply a seemingly unrelated regression approach to investigate the impact of technological change and drilling costs on oil exploration and yield per effort at regional and field levels. They develop a weighting index for technological change, considering the significance and impact of various technological innovations on offshore oil and gas exploration, rather than by using a time trend proxy. Kemp and Kasim (2006) develop a regional exploration behavior model for the UK continental shelf. They apply the three-stage least squares estimation method on annual data for 1975-2002 to examine the effects of the economy, technology, resource depletion, tax, and expected reserves (yet to be discovered) on exploration efficiency and finding cost across five petroleum producing regions in the UK. It is worth noting that taxes have been found quite influential determinants of foreign investment in US oil exploration abroad (Solomon, 1989).

Mohn (2008) reports that oil price exerts a significant positive influence on exploration drilling, discovery rate, and size of discovery. The award of new acreage also enhances reserves additions from its positive influence on exploration drilling and discovery size. Technology has a significant but inelastic influence on reserves additions and offsets the negative effect of depletion. Osmundsen *et al.* (2010) examined the drivers of exploration investment behavior from the perspective of drilling efficiency. Their model analyzed the influence of water depth, meters, temperature, total number of exploration wells drilled, technological changes, lagged oil price, and several dummies of rigs, status of wells, type of oil companies, location of wells, and type of wells on exploration drilling efficiency.

Other part of literature identifies the relationship between the oil prices and the exploration investment. The latter is riskier and capital intensive, is mostly self-financed. Thus, characterizing the effect of oil price changes on exploration investment leads to mixed findings in the literature owing to differences between the countries, regions, and methodologies applied. Emeka *et al.* (2012) applied a vector autoregressive model on Nigeria's average annual daily crude oil production as proxy for exploration activity and the Brent crude spot prices to explore the relationship between oil prices and exploration activity in Nigeria. They find that an increase in oil prices does not Granger cause exploration activity but Granger causes oil production. Conversely, Guerra (2007) specified a vector autoregressive model and estimated the causality and responsiveness of oil investment to oil price changes in OPEC and non- OPEC countries. He used the aggregate number of oil rigs as proxy for oil investment and tested the effect of oil production of the OPEC and non-OPEC producers, the Brent oil price in real terms on oil investment, and the OECD activity index as proxy for world oil demand. He found that the aggregate oil investment responds greatly to oil price changes and a barely significant response of oil price shocks to oil investment, but with transitory behavior. The responsiveness of the OPEC and non-OPEC investment levels to permanent oil price changes is at the highest levels of 2.5 and 4.9 percent, respectively. Ringlund *et al.* (2008) analyzed the estimated dynamic relationship between rig activity and oil prices to determine the responsiveness of rig activity, as proxy for exploration activity, to changes in oil prices in non-OPEC countries.

The above mentioned revision of the related studies (Emeka *et al.*, 2012; Farzin, 2001; Guerra, 2007; Iledare and Pulsipher, 1999; Kemp and Kasim, 2006; Kettis, 2004; Managi *et al.*, 2005; Michot, 2000; Mohn, 2008; Osmundsen *et al.*, 2010; Ringlund *et al.*, 2008) show three distinct research points. First, there is not a consensus regarding the determinants of oil and gas exploration investment. In terms of business administration, these common determinants help pave the way to a good management of exploration investments. Second, in terms of economics, the majority of studies examine firm-level determinants rather than economic determinants. The latter are of especial interest to practitioners as well as policy makers as far as the macroeconomic variables constitute systematic influences on all oil and gas firms in the industry. Third, the above mentioned studies do not examine all relevant measures of exploration investments. In this regard, the literature on measures of corporate investment shows that the appropriate performance measures must include risk and return elements. The authors argue that the performance measures that are quite relevant to the oil and gas industry are growth and risk measures that are treated in this study as dependent variables.

Egyptian oil and gas industry

Economic importance

The energy sector is of vital importance to Egypt's economy and is going from strength to strength. Crude oil, natural gas, and petroleum products combined accounts for 12.9 percent of total GDP in 2010/2011. There are currently more than 60 international petroleum companies working in Egypt, investing more than US$2 billion annually. Substantial discoveries, initiation of gas exports and tangible progress in the emerging petrochemical sector meant that the growth rate of natural gas industry in the private sector was 6.3 percent in the fiscal year 2009/2010, and in the oil products industry reached a remarkable 23.8 percent. These both favorably compare to the average growth rate in the private sector of 4.2 percent. Along the past few years, exports of oil, gas and petrochemicals products recorded US$4.5 billion on average; oil exports alone were equivalent to 14 percent of foreign exchange receipts, which represents the second largest source of FX for Egypt after tourism (Central Bank of Egypt, 2011 annual report).

Industry structure

The petroleum industry in Egypt is managed by the Ministry of Petroleum under which four holding companies function as government agencies involved in oil, gas, petrochemical, and Upper Egypt development activities. The Egyptian General Petroleum Holding Corporation (EGPC), the Egyptian Natural Gas Holding Company, the Egyptian Petrochemicals Holding Company, and Ganoub El Wadi Petroleum Holding Company are wholly owned state companies that represent the Egyptian Government.

Besides the holding companies there are multinational and Egyptian private sector companies operating in the sector, which are granted concession areas to explore via periodic bidding rounds administered by the relevant holding agency. Currently there are around 60 multinational and international companies that operate in the exploration, excavation, and production of oil and gas in Egypt and their market share are shown in Figure 1.

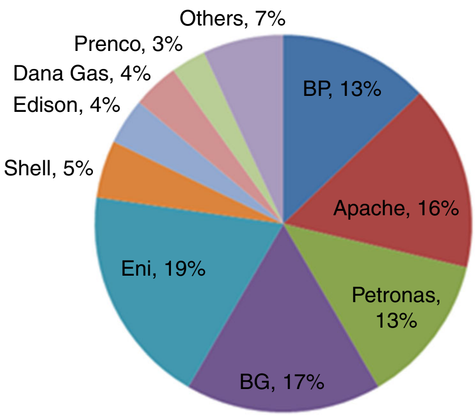
Oil and gas reserves

Estimating crude oil reserves is one of the most controversial issues to an oil producing country. Reserves are considered strategic issues and typically involve a lot of manipulation and inconsistencies across different assessors. With no major discoveries taking place between 1999 and 2013/2014, the remaining reserves have increased by adding the condensate, estimated at around 1.8 billion barrels, making the official estimates of 4.4 billion (BP, 2013/2014). The level of natural gas reserves have increased due to new discoveries, with condensates reserves following closely.

In Egypt, the largest concentration for reserves, is found in the Gulf of Suez 74 percent. The Western Desert has only 15 percent of the total oil in place followed by the Eastern Desert with about 10 percent of the oil in place (EGPC primary data). The Mediterranean reserves along with the Nile Delta account for more than 80 percent of the total reserves according to PICO (2013) industry report. The balance of the reserves are divided between the Western Desert that followed by the Gulf of Suez. Most of the undeveloped reserves lie within the Mediterranean Sea basin.

Egypt oil supply and demand

Table I.



Source: EGPC primary data

Figure 1. International companies market share in Egypt

Egypt gas production and net exports
Table II.

Data, statistical test, and estimation methods

Sample firms

The sample firms include 44 major oil and gas companies working in Egypt. The country-level data are obtained from many sources including the Central Bank of Egypt, the World Bank (World Development Indicators) and International Monetary Fund (IMF). The capital expenditure (CAPEX) and operating expenditure (OPEX) for the IOCs are controlled for by using primary and secondary data that are obtained from Wood Mackenzie (2013) and Ministry of Petroleum in Egypt. Table III reports the definition and source of the variables examined in this study. The data cover the period of 2009-2014. It is worth mentioning that, although the relative scarcity of comprehensive firm-level variables that are related to oil and gas exploration, the authors have surveyed the most relevant studies to extract the very relevant variables. The relevant studies are Reiss (1990), Emeka *et al.* (2012), Farzin (2001), Guerra (2007), Iledare and Pulsipher (1999), Kemp and Kasim (2006), Kettis (2004), Managi *et al.* (2005), Michot (2000), Mohn (2008), Osmundsen *et al.* (2010) and Ringlund *et al.* (2008). Regarding the macroeconomic variables, the authors rely on the common macroeconomic variables that are reported by the IMF in its annual World Economic Outlook reports, which are publicly available at: www.imf.org/external/pubs/ft/weo/data/assump.htm

Statistical tests

The Anderson and Darling (1952, 1954) test is used to examine the normality of the collected data. The results indicate that the independent variables are not normally distributed. The variables are converted into normal values using the Van der Waerden method (Van der Waerden, 1927, 1930, 1931). The Hausman specification test is used to identify whether the fixed or random effects model should be used (Hausman, 1978; Hausman and Taylor, 1981). The test examines correlation between the observed

Table I.
Egypt oil production and net exports

	2011	2012	2013	2014	2015	2016
Crude oil, NPGL and liquids mbbl/d	728.5	722.8	729.4	737.3	742.7	736.6
Change Y-o-Y %	1.2	−0.8	0.9	1.1	0.7	−0.8
Crude and liquids net exports	107.8	83.5	70.9	59.1	44.1	17.1
Change Y-o-Y %	−8.3	−22.5	−15.1	−16.6	−25.4	−61.2

Source: Ministry of Petroleum, CAPMAS

Table II.
Egypt gas production and net exports

	2011	2012	2013	2014	2015	2016
Dry natural gas production, bcm	61.3	61.2	61.2	62.5	64.9	66.9
Change Y-o-Y %	−0.1	0	0	2.0	4.0	3.0
Dry Natural gas consumption, bcm	50.8	50.7	50.7	52.7	55.1	58.2
Change Y-o-Y %	9.9	0	0	3.8	4.6	5.6
Dry natural gas net exports	10.5	10.5	10.5	9.8	9.9	8.7

Independent Variables		Source
Firm-level variables		
$x1$	Production (000boe/day)	WoodMac, MoP
$x2$	Capital expenditure (CAPEX) US$ million	WoodMac, MoP
$x3$	Operating expenditure (OPEX) $/boe	WoodMac, Mop
$x4$	Initial Liquid Reserves (Mmbbl)	WoodMac, MoP
$x5$	Remaining gas reserves (Bcf)	WoodMac, MoP
$x6$	Remaining Boe reserves (Mmboe)	WoodMac, MoP
$x7$	Oil Brent Price ($/bbl)	WoodMac
Country-level variables		
$x8$	Current account balance (BoP, current US$)	IMF
$x9$	Current account balance (% of GDP)	IMF
$x10$	Foreign direct investment, net (BoP, current US$)	IMF
$x11$	Market capitalization of listed companies (current US$)	IMF
$x12$	Market capitalization of listed companies (% of GDP)	IMF
$x13$	External debt stocks, total (DOD, current US$)	IMF
$x14$	External debt stocks (% of exports of goods, services and primary income)	IMF
$x15$	Debt service on external debt, total (TDS, current US$)	IMF
$x16$	Energy production (kt of oil equivalent)	MoP
$x17$	Energy use (kt of oil equivalent)	MoP
$x18$	Total reserves (includes gold, current US$)	IMF
$x19$	Total reserves (% of total external debt)	CBE
$x20$	Total reserves minus gold (current US$)	CBE
$x21$	Inflation, consumer prices (annual %)	CAPMAS
$x22$	Lending interest rate (%)	CBE
$x23$	Risk premium on lending (lending rate minus treasury bill rate, %)	IMF
$x24$	Domestic credit to private sector (% of GDP)	CBE
$x25$	Cash surplus/deficit (current LCU)	IMF
$x26$	Subsidies and other transfers (current LCU)	IMF
$x27$	Gross national expenditure (% of GDP)	IMF
$x28$	Adjusted savings: energy depletion (current US$)	IMF
$x29$	Adjusted savings: energy depletion (% of GNI)	IMF
$x30$	GDP (current US$)	CBE
$x31$	GDP growth (annual %)	CBE
$x32$	GDP per capita (current US$)	CBE
$x33$	Gross savings (current US$)	IMF
$x34$	Gross savings (% of GDP)	IMF
$x35$	Unemployment, total (% of total labor force) (national estimate)	IMF
$x36$	Political Risk Rating A.M. BEST (1-5)	A.M. BEST Report
$x37$	Political risk rating EKN (1-7)	EKN Report
$x38$	Political risk rating AON (1-6)	AON Corporation (2004) report
$x39$	Political risk rating MIGA – World Bank (1-20)	World Bank
$x40$	Political risk rating HIS (1-100)	HIS Report
$x41$	Credit risk rating Moody's	Moody's
$x42$	Credit risk rating S&P	Standard & Poors
$x43$	Credit risk rating FITCH	FITCH

Table III. List of independent variables and sources of data

x_{it} and the unobserved λ_k, hence is run under the hypotheses that follow:

$$H_0: \operatorname{cov}(x_{it}, \lambda_k) = 0, \text{ or random effect}$$

$$H_1: \operatorname{cov}(x_{it}, \lambda_k) \neq 0, \text{ or fixed effect}$$

where x_{it} is the independent variable (regressor), and λ_k the error term.

The results of the test show that the random model fits the distribution of the data. Therefore, Lagrange multiplier is used for standardizing the variances across firms for the dependent and independent variables (Briand and Carter, 2011). The issue of linearity vs non-linearity is addressed and examined as well. The regression equation specification error test (Ramsey, 1969; Thursby and Schmidt, 1977, 1979; Sapra, 2005; Wooldridge, 2006) is used for testing the two hypotheses that follow:

$$H_0\text{: } \hat{\gamma}^2, \hat{\gamma}^3 = 0$$

$$H_1\text{: } \hat{\gamma}^2, \hat{\gamma}^3 \neq 0$$

The null hypothesis refers to linearity and the alternative refers to non-linearity. The results of F test ($\alpha = 1$ percent) show that the F statistic is greater than the critical value leading to the rejection of the null hypothesis, thus a nonlinear model is appropriate[1].

Discriminant, content, and construct validity

An examination for the discriminant validity, content, and construct validity is necessary for ensuring the effectiveness of the discriminant analysis and the resulting discriminant model (Podsakoff and Organ, 1986). The classifications and the use of firm-specific and country-specific ratios provide unique dimensionality, which implies that the discriminant validity is confirmed. With regards to the construct and content validity, firm-specific and country-specific ratios are extracted from the relevant literature where multidimensional perspectives are provided. Moreover, the ratios cover unique dimensions of performance, thus providing an adequate basis for content validity (Nunnally, 1978). These variables offer sufficient evidence of construct validity given that numerous related studies have empirically investigated these ratios in the literature on investment performance measurement.

Estimation of the discriminant models

The discriminant analysis is a common technique used for developing Z-score models. The latter addresses the problem of the separation of two or more groups of observations (i.e. individuals and companies), given measurements for these observations on several variables (Hair *et al.*, 1995; Manly, 1998). The objective of the discriminating function is to classify an observation into one of several a priori groupings dependent upon the individual characteristics of the observation. In theoretical terms, the main application of the discriminant analysis is to categorize and/or make forecasts for situations in which the dependent variable is measured in qualitative terms. In this study, the qualitative factor is low and high levels of three dependent variables: monetary values of exploration investments, growth of exploration investments and VaR of exploration investments.

The use of discriminant analysis in the field of business is quite rich. Several studies used variety of applications of the discriminant analysis in order to forecast corporate solvency (Sinkey and Joseph, 1975; Taffler, 1984). The Z-score models are also used in other applications that include the examination of corporate transitional performance (Eldomiaty, 2005), monitoring growth of the firm (Eldomiaty and Rashwan, 2011), and the examination of the markets risks; both the systematic and non-systematic components (Eldomiaty *et al.*, 2011).

Discriminant function analysis

Functions of the variables $X_1, X_2, \ldots, X_p$ are presented by the discriminant analysis, in an attempt to separate the m groups with high probability. The most straight forward approach involves taking a linear combination of the X variables as follows:

$$Z = a_1X_1 + a_2X_2 + \cdots + a_pX_p$$

In this form, the Z reflects group differences. Groups can be separated using Z if the mean value differs considerably from a group to another, with the values within a group being fairly constant. Deciding on the discriminant coefficients $a_1, a_2, \ldots, a_p$ in the index can be done through maximizing the F ratio for a one-way analysis of variance. Accordingly, a suitable function for the splitting of the groups can be described as the linear combination for which the F ratio is as large as possible. When this approach is employed, it may be possible to decide on several linear combinations for the separation of groups. In general, the number available is the smaller of p and $m-1$. The reduction of the space dimensionality (i.e. from the number of different independent variables X to $m-1$ dimension(s)) is one of the advantages of the linear discriminant analysis. Since this study is concerned with two groups (e.g. two levels of the three dependent variables above mentioned), the resulting Z function is only one function (i.e. one-dimensional analysis).

When the discriminant coefficients are applied to the actual ratio, a basis exists for classification into one of the mutually exclusive groupings. In that sense, the discriminant analysis technique has the benefit of taking into consideration an entire spectrum of characteristics that are common to the relevant observations (e.g. oil and gas firms) as well as the interaction of these characteristics with each other. Another benefit for the linear discriminant analysis is that it yields a model with a considerably small number of selected measurements, which potentially conveys large quantities of information (Altman, 1968, 1971; Altman and Sametz, 1977).

The Z-score models

The authors derive three linear discriminating functions with their Z scores. These functions can help monitor the performance of exploration investments in the oil and gas firms. The stepwise selection algorithm produces certain statistically significant variables as predictors of grouping. The discriminating functions are significant at 95 percent confidence level. Table IV shows the discriminating functions with their standardized coefficients.

The results for the Z-score model showed that the Ln exploration investments has resulted in nine of the determinants of which three determinants are related to both firm-level and country-level, namely, the CAPEX that the IOCs' are already investing in their current oil and gas projects, which has the highest coefficient of 0.8247 that shows the importance of such determinants to the level of exploration investment, the second determinants is the external debt stocks as a percentage of exports of goods, services and primary income with a coefficient of 0.4061, which is also very relevant because the more exports of goods including oil and gas products the more lucrative for the IOCs to invest in exploration in such country to get the benefit of instant cash-flow streams in case of the exploration success. Also, the Ln of GDP in nominal current US$ showed a negative coefficient of −0.9283, and the authors are assuming that this is because the oil and gas exploration is different than the oil and

Components of the Z models	Equation coefficients[a] Ln exploration investments	Growth of exploration investments	VaR (99%) for exploration investments
CAPEX US$ million	0.8274		
External debt stocks (% of exports of goods, services and primary income)	0.4061		
Ln GDP (current US$)	−0.9283		
ENAP	0.3435		
GDF Suez	0.3034		0.9055
Kuwait Energy Company (KEC)	0.3560	−4.710	
Mitsui & Co.	−0.3536		
Petronas Carigali	−0.3405		
Shell	0.3325	9.290	
OPEX ($/boe)		31.304	
Remaining Gas Res. bcf		−2.362	
BG		0.786	0.4690
Circle Oil		9.664	
Dana Gas		10.284	
Dover Investments Limited		−1.701	0.9055
Edison		11.366	
Eni		−1.928	
Gharib Oil Services		−11.481	
Kuwait Petroleum Corporation		−4.143	0.9055
LUKOIL		5.458	
MB Petroleum		−3.138	
METI (Japan)		7.105	
MOL		−5.968	
National Oil Production Co.		−19.498	0.6557
Private Investors		3.887	0.6557
RWE Dea		−5.921	0.9055
Sea Dragon		4.466	1.0000
Sojitz Corporation		−2.500	
Government of Croatia			0.7937
NaftoGaz			0.6557
Petroceltic			1.0000
Petronas Carigali			0.9055
Eigenvalue[b]	0.729	583.616	4.400
% of variance	100	100	100
Canonical correlation	0.649	0.999	0.903
Wilks λ	0.578	0.002	0.185
x^2	69.294***	627.539***	155.149***
n	133	111	100

Notes: [a]Standardized canonical discriminant function coefficients that are statistically significant at 95 percent confidence interval; [b]the variance in a set of variables explained by a factor or component and denoted by λ. An eigenvalue is the sum of squared values in the column of a factor matrix, or $\lambda_k = \sum_{i=1}^{m} a_{ik}^2$ where a_{ik} is the factor loading for variable i on factor k, and m is the number of variables. ***Significant at 1 percent level

Table IV. The components of the discriminant models for low-high exploration investments

gas production, and IOC usually invest in exploration in frontier areas where the GDP is not really the main factor of the country entry.

For the growth of the exploration investments a two main determinants were reached and both are firm-level related variables, namely, the OPEX ($/boe) and the remaining gas reserves (bcf). The OPEX showed a very positive coefficient of 31.304 which sounds reasonable because when the company has a control on its operating expenses will tend more to grow its exploration investment. The remaining reserves had a low negative coefficient of −2.362 which also sound reasonable because the data showed that Egypt in general is facing a decline in the remaining reserves which accelerate the economic limit date of the IOCs' existing concessions and considering other country-level variables, it would make more sense that companies with a declining remaining reserves would not increase its exploration investment levels.

The authors calculated the cut-off points on the *Z*-Scale using the estimated prior probability ratios. The cut-off points on the *Z*-scale are shown in Table V. The cut-off points are calculated as Ln (*P*1/*P*2), where P*1* is the prior probability of low exploration investments and P2 is the prior probability of high exploration investments. The prior probability ratio is an estimate of the proportion of firms with a ratio profile more similar to those of groups 1 and 2.

The relative contribution of the model's discriminatory power

The usefulness of the discriminant analysis is that the profile of the final variables shows the relative contribution of each variable to the total discriminatory power of the *Z*-score model and the interaction between them. The common approach to the assessment of the relative contribution is based on measurement of the proportion of the Mahalanobis D^2 or the distance between the centroids of the two constituent groups accounted for by each variable (Mosteller and Wallace, 1963). It calculates as follows:

$$P_j = \frac{c_j\left(\overline{r}_{jf} - \overline{r}_{js}\right)}{\sum_{i=1}^{4} c_j\left(\overline{r}_{if} - \overline{r}_{is}\right)}$$

where P_j is the proportion of the D^2 – distance accounted for by ratio *j*; $\overline{r}_{if}$ and $\overline{r}_{is}$ the means of the below-median and above-median groups for ratio *i*, respectively.

Table VI shows that:

(1) For the Ln exploration investments the main relative contribution are consistent with the discriminant models of low and high exploration investments and showed that the key three determinants of CAPEX. External debt and Ln GDP have the contribution of 19.74, 9.69 and 22.15 percent, respectively, a total of more than 50 percent of all other variables.

(2) For the growth of exploration investments, the highest weights were for OPEX 19.94 percent, the National Oil Company 12.42 percent, Gharib Oil Services 7.31 percent, the Italian EDISON 7.24 percent and the Emirates' Dana Gas 6.55 percent. The results is very meaningful in terms of political turmoil of Egypt since 2011, which made the government owned companies (National Oil Company and Gharib oil) to invest more in exploration to tighten the gap from IOCs reluctance to invest in exploration.

Prior probability	Low exploration investments	High exploration investments	Cut-off point
Ln exploration investments	0.496	0.504	−0.015
Growth of exploration investments	0.495	0.505	−0.018
VaR (99%) for exploration investments	0.550	0.450	0.201

Table V. The cut-off points for low-high exploration investments models

Components of the Z models	Relative contribution (%)[a] Ln exploration investments (%)	Growth of exploration investments (%)	VaR (99%) for exploration investments (%)
Capital expenditure (CAPEX) US$ million	19.74		
External debt stocks (% of exports of goods, services and primary income)	9.69		
Ln GDP (current US$)	22.15		
ENAP	8.20		
GDF Suez	7.24		9.28
Kuwait Energy Company	8.49	3.00	
Mitsui & Co.	8.44		
Petronas Carigali	8.12		
Shell	7.93	5.92	
Operating expenditure (OPEX) $/boe		19.94	
Remaining Gas Reserves (bcf)		1.50	
BG		0.50	4.81
Circle Oil		6.16	
Dana Gas		6.55	
Dover Investments Limited		1.08	9.28
Edison		7.24	
Eni		1.23	
Gharib Oil Services		7.31	
Kuwait Petroleum Corporation		2.64	9.28
LUKOIL		3.48	
MB Petroleum		2.00	
METI (Japan)		4.53	
MOL		3.80	
National Oil Production Co.		12.42	6.72
Private Investors		2.48	6.72
RWE Dea		3.77	9.28
Sea Dragon		2.85	10.25
Sojitz Corporation		1.59	
Government of Croatia			8.13
NaftoGaz			6.72
Petroceltic			10.25
Petronas Carigali			9.28

Source: [a]Mosteller-Wallace measure

Table VI. The relative contribution of the models' discriminatory power

(3) For the VaR for exploration investments the highest weights were for Kuwait Peteroleum Corporation 9.28 percent, Sea Dragon 10.25 percent, Petroceltic 10.25 percent, Dover investments 9.28 percent, and GDF Suez 9.28 percent. It is worth mentioning that all these IOCs are new entrants to the Egyptian oil and gas market and despite the political turmoil they invested massively in the exploration of oil and gas.

The accuracy matrix of the Z model

In a multigroup case, the discriminant analysis produces a measure of success, which is a classification table or so-called accuracy matrix, as shown in Table VII.

The actual group membership is equivalent to the a priori groupings utilized by the model in an attempt to classify these profitability groups correctly.

At this stage, the model is basically explanatory. In addition, the discriminant model produces a predictive function as long as new groups are classified. The Hs (Hits) stand for correct classifications and the Ms (Misses) stand for misclassification. M_1 represents a Type I error and M_2 represents a Type II error. The jack-knife test, or Lachenbruch holdout test (Lachenbruch, 1967) is a well-known statistical test to produce a classification table. The final results of the jack-knife test are shown in Table V. Types I and II errors can be easily observed according to the accuracy matrix shown in Table V. It is worth noting that Table V shows that Types I and II errors are less than the Hs (Hits) in both groups of low and high exploration investments. This result supports the high relative reliability of the estimated discriminant models.

Table VIII shows that the three discriminant models have different discriminant power. In total, 81.8 percent for the Ln exploration investments and 100 percent for both growth of exploration investments and VaR (99 percent) for exploration investment. This indicates that IOCs are mostly exposed to the various risks when it comes to the exploration investment assessment. Nevertheless, Table V shows very important implications (which also are an advantage to the use of discriminant analysis to examine the exploration growth that the contribution of exploration

Table VII. The accuracy matrix for the discriminant analysis

	Predicted group membership	
Actual group membership	Low	High
Low	H	M_1
High	M_2	H

Table VIII. Lachenbruch holdout test (jack-knife test), low-high exploration investments

Actual group membership	No. of cases	Predicted group membership	
Ln exploration investments[a]			
		Low	High
Low	66	54	12
		81.8%	18.2%
High	67	16	51
		23.9%	76.1%
Growth of exploration investments[b]			
		Low	High
Low	55	55	0
		100%	0%
High	56	0	56
		0%	100%
VaR (99%) for exploration investments[c]			
		Low	High
Low	55	55	0
		100%	0%
High	45	5	40
		11.1%	88.9%

Notes: [a]Percent of grouped cases correctly classified: 78.9; [b]percent of grouped cases correctly classified: 100; [c]percent of grouped cases correctly classified: 95.0

growth (100 percent) is higher than the contribution of the Ln Exploration investments ratio (81.8 percent). This result also shows that VaR for exploration investment growth depends more on the combined growth exploration investments and Ln exploration investments.

Cointegration analysis

The objective of this analysis is to extend the robustness of the above mentioned estimation processes. Cointegration analysis offers the benefit of showing not only the significance of the estimates but also the cointegration between each predictor and the dependent variable (Banerjee and Carrion-i-Silvestre, 2006; Hong and Wagner, 2011; Johansen, 2012; Kao and Chiang, 2000; Mark and Sul, 2003; Philips, 1998).

This section includes two parts. The first part shows the results of cointegration regression. The second part shows the results of Johansen cointegration test.

First: cointegration regression

This type of regression extends the ordinary least square estimation to a cointegration between each predictor and the dependent variable. The estimation results show not only the significance but also the coherence of the estimated coefficients.

Table IX reports the estimates of cointegration regression for the parameters reported in Table IV being significant in each regression equation that represents a distinct performance measure.

Second: Johansen cointegration test

This test adds to the robustness of the above mentioned regression estimates in Table IX. The test is quite practical for examining the cointegratuon in multiple regression equation. The objective is to show how many variables are cointegrating with each performance measure significantly. The results are reported in Tables X-XII that follow.

Table X shows that a significant cointegration exists between natural logarithm of exploration investment and the first level that includes CAPEX (US$ million). This results indicates the coherence between capital expenditure and exploration investments which offers an evidence on the robustness of the estimated coefficient of CAPEX (US$ million) as reported in Table IX.

Table XI shows that a significant cointegration exists between growth of exploration investments and firm dummies. Considering that OPEX ($/boe) is statistically significant as reported in Table IX, this estimate is not cointegrating with growth of exploration investment significantly. The results in Table XI also show that growth of exploration investment varies significantly among firms.

Table XII shows that a significant cointegration exists between VaR of exploration investments and firm dummies. These results carry the same implications as in Table XI that VaR of exploration investment varies significantly among firms as far as it is influenced only by firms' dummies. The case is otherwise for the US firms (Hvozdyk and Blackman, 2010) that risk of exploration investments are quite robust to all firms.

Conclusion

The literature on performance measures in oil and gas industry lacks a consensus regarding the relevant performance measure. This requires an examination of three

	Ln exploration investments	Growth of exploration investments	VaR (99%) for exploration investments
Constant	2,143.53	92,294.96	16,404.77
Capital expenditure (CAPEX) US$ million	7.8024 (6.9277)***		
External debt stocks (% of exports of goods, services and primary income)	0.8422 (1.7436)*		
Ln GDP (current US$)	−1.2931 (−5.0456)***		
ENAP	1,133.18 (1.6952)*		
GDF Suez	1,083.80 (1.8599)**		36.302 (0.6883)
Kuwait Energy Company	1,075.75 (1.6066)	−0.0544 (−1.5127)	
Mitsui & Co.	−1,107.59 (−2.3182)**		
Petronas Carigali	−2,531.43 (−2.9691)***		
Shell	808.21 (1.3879)	−0.0607 (−0.9083)	
Operating expenditure (OPEX) $/boe		−0.0117 (−4.4516)***	
Remaining gas reserves (bcf)		−0.00006 (−0.2968)	
BG		−0.0605 (−0.5883)	28.788 (0.2521)
Circle Oil		−0.1432 (−3.9019)***	
Dana Gas		−0.0781 (−1.2914)	
Dover Investments Limited		−0.8190 (−19.36)***	360.05 (6.8276)***
Edison		−0.1298 (−1.5892)	
Eni		0.0399 (0.3288)	
Gharib Oil Services		0.0435 (1.104)	
Kuwait Petroleum Corporation		−4.143-0.0311 (−0.7366)	40.167 (0.7616)
LUKOIL		−0.0621 (−1.4632)	
MB Petroleum		−0.0206 (−0.5656)	
METI (Japan)		−0.6611 (−17.77)***	
MOL		0.0052 (0.1458)	
National Oil Production Co.		0.1961 (2.6094)***	3,745.45 (71.02)***
Private Investors		−0.0665 (−1.8431)**	34.303 (0.4213)
RWE Dea		0.0798 (0.6315)	437.84 (8.303)***
Sea Dragon		−0.0908 (−1.2677)	34.312 (0.6506)
Sojitz Corporation		0.0133 (0.3623)	
Government of Croatia			702.72 (13.325)***
NaftoGaz			29.5068 (0.3624)
Petroceltic			42.205 (0.8003)
Petronas Carigali			62.101 (1.177)
$\bar{R}^2$	0.3066	0.9408	0.9478
Standard error of regression	153.96	48,238.22	2,803,487
n	133	111	110

Notes: [a]The estimates are fully modified least squares (FMOLS) using long-run covariance estimate (Bartlett kernel, Newey-West fixed bandwidth = 5). *,**,***Significant at 10, 5 and 1 percent level, respectively

Table IX. Results of cointegration regression for the predictors of low-high exploration investment[a]

well-known performance measures, namely, amount of exploration investments, its growth and risk. The authors specify and estimate the exploration behavior equations by using discriminant models and cointegration analysis. The objective is to examine the influence of competing economic-specific and firm-specific factors on exploration

Table X. Johansen cointegration results for Ln exploration investments (trace and maximum eigenvalue)

No. of CE(s)	Trace test Statistic	Eigenvalue	Probability[a]	Max-eigenvalue test Statistic	Eigenvalue	Probability[a]
None[a]	281.5769	0.4133	0.0001	68.2603	0.4133	0.0210
At most 1[a]	213.3166	0.3678	0.0062	58.7022	0.3678	0.0470
At most 2	154.6144	0.2598	0.0897	38.4997	0.2598	0.5891
At most 3	116.1147	0.2213	0.1638	32.0105	0.2213	0.6568
At most 4	84.1042	0.1826	0.2410	25.8104	0.1826	0.7151
At most 5	58.2938	0.1579	0.2915	21.9993	0.1579	0.6077
At most 6	36.2945	0.1096	0.3817	14.8638	0.1096	0.7589
At most 7	21.4307	0.1066	0.3313	14.4226	0.1066	0.3314
At most 8	7.0082	0.0459	0.5767	6.0205	0.0459	0.6106
At most 9	0.9877	0.0077	0.3203	0.9877	0.0077	0.3203

Notes: Critical values are reported by MacKinnon *et al.* (1999). [a]Probabilities are computed using asymptotic χ^2 distribution

Table XI. Johansen cointegration results for growth of exploration investments (trace and maximum eigenvalue)

No. of CE(s)	Trace test Statistic	Eigenvalue	Probability[a]	No. of CE(s)	Max-eigenvalue test Statistic	Eigenvalue	Probability[a]
None	3,044.24	1.00	n/a	None	838.41	1.00	n/a
At most 1	2,205.83	0.99	n/a	At most 1	482.92	0.99	n/a
At most 2	1,722.91	0.96	n/a	At most 2	333.83	0.96	n/a
At most 3	1,389.08	0.91	n/a	At most 3	252.26	0.91	n/a
At most 4	1,136.81	0.86	n/a	At most 4	210.79	0.86	n/a
At most 5[a]	926.02	0.84	0.00	At most 5[a]	195.93	0.84	0.00
At most 6[a]	730.09	0.79	0.00	At most 6[a]	163.49	0.79	0.00
At most 7[a]	566.60	0.76	0.00	At most 7[a]	152.41	0.76	0.00
At most 8[a]	414.20	0.63	0.00	At most 8[a]	104.77	0.63	0.00
At most 9[a]	309.43	0.54	0.00	At most 9[a]	81.50	0.54	0.00
At most 10[a]	227.93	0.51	0.00	At most 10[a]	76.30	0.51	0.00
At most 11[a]	151.63	0.44	0.00	At most 11[a]	61.50	0.44	0.00
At most 12[a]	90.13	0.28	0.00	At most 12[a]	34.52	0.28	0.04
At most 13[a]	55.61	0.21	0.01	At most 13	25.56	0.21	0.09
At most 14[a]	30.05	0.15	0.05	At most 14	17.50	0.15	0.15
At most 15	12.56	0.11	0.13	At most 15	12.19	0.11	0.10
At most 16	0.37	0.00	0.55	At most 16	0.37	0.00	0.55

Note: Critical values are reported by MacKinnon *et al.* (1999). [a]Probabilities are computed using asymptotic χ^2 distribution

investments in the oil and gas industry in Egypt. As far as variations in exploration investments on firm level are observed, a discriminant analysis (*Z* model) is quite useful in terms of showing the determinants of exploration investment for those firms that are involved in high- and low-exploration investments. The estimates by the dynamic *Z* model and cointeragtion analysis show that the associations between performance measures of exploration investments, firm-specific and country-specific determinants are intrinsically nonlinear and highly cointegrated at firm level. The estimated models perform satisfactorily in terms of parameter significance, specification tests, and general model diagnostics.

The general conclusion is that the amount of exploration investment is an appropriate performance measure than growth or risk. In addition, the amount of exploration investment is influenced significantly by both firm-specific variable (CAPEX) and country-specific variables (external debt stocks and GDP).

Managerial implications

Upstream oil and gas development requires large and continuous investment. This study examines the robust performance measure that oil and gas firms in Egypt should adopt. The final results provide a road map to the management of exploration investments. Firms' management must focus on CAPEX along with monitoring the influences of macroeconomic variables such as external debt stocks and GDP. It is worth noting that firms' management must rationalize the OPEX as far as a negative association is observed.

This information is critical to firm's management when negotiating the terms of business contracts in any country. That is, firms' management should be concerned with the amount of capital expenditure and operating expenditure when planning for business growth. As far as VaR of exploration investment is concerned, the significant firm dummies indicate that the riskiness of exploration investment varies among firms and can be controlled by firms but the techniques for measuring VaR are not adopted by the firms in the industry systematically.

The managerial contribution of this study is present in terms of developing discriminants models (*Z* scores) that can be used by firms' management for monitoring the relevant aspect of firm performance in the oil and gas industry. In addition, firms' management can use the amount of exploration investment as a robust measure of performance.

Recommendations and future research

As suggested by Nawaz and Hood (2005) and Kettis (2004), there does not appear to have been much research carried out in the exploration investment area. An examination of a robust performance measure is, therefore, important in order to determine where the field stands today and the trends that are emerging. This study has contributed to the understanding of the managerial concerns of examining the determinants of the exploration investment in an emerging country. For this purpose, future research might be extended in a cross-national level to explain whether robust exploration investment performance measures are universal or country specific.

	Trace test			Max-eigenvalue test		
No. of CE(s)	Statistic	Eigenvalue	Probability[a]	Statistic	Eigenvalue	Probability[a]
None[a]	1,454.15	1.00	1.00	667.21	1.00	0.00
At most 1[a]	786.95	0.97	0.00	359.05	0.97	0.00
At most 2[a]	427.90	0.79	0.00	163.86	0.79	0.00
At most 3[a]	264.04	0.64	0.00	105.89	0.64	0.00
At most 4[a]	158.15	0.61	0.00	98.32	0.61	0.00
At most 5[a]	59.83	0.24	0.00	29.47	0.24	0.03
At most 6[a]	30.36	0.20	0.04	24.00	0.20	0.02
At most 7	6.36	0.05	0.65	5.47	0.05	0.68
At most 8	0.89	0.01	0.35	0.89	0.01	0.35

Note: Critical values are reported by MacKinnon *et al.* (1999). [a]Probabilities are computed using asymptotic χ^2 distribution

Table XII. Johansen cointegration results for $VaR_{99\%}$ exploration investments (trace and maximum eigenvalue)

Note

1. $F-\text{statistic} = \left((\text{SSE}_R - \text{SSE}_U)/J\right)/\left(\text{SSE}_\text{U}/(T-K)\right)$, where SSE_R and SSE_U are the sum squared errors for the restricted and unrestricted models respectively, J refers to the two hypotheses under consideration, T is the number of observations, and K is the number of regressors.

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