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# Valuing an offshore oil exploration and production project through real options analysis☆

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ABSTRACT

To be useful to project managers, real option analysis (ROA) needs to capture the unique characteristics of individual projects and, at the same time, remain tractable and intuitive. That is a challenge since actual projects are often complex, featuring multiple sources of uncertainty as well as multiple investment and operating options. To meet the challenge, ROA has to take a clinical approach to project management and valuation, tailoring its framework to the specifics of each individual project to reflect its main sources of flexibility without becoming overly complex. This paper undertakes a ROA of an offshore oil development project of an integrated oil and gas company. The sequence and interconnections of available real options – exploration options, appraisal options, scaling options and abandonment options – as well as the calibration of the model's parameters, are developed in close collaboration with the Exploration and Production (E&P) division of the company, to assure realism and adherence to what management believes are the key sources of investment flexibility in a typical offshore project. The project assumes that there is joint uncertainty about reserve size and the price of oil. While the first source of uncertainty is resolved through exploration and appraisal activities the second is resolved through a diffusion model. The available real options add a substantial value to the project, with the option to abandon being the most valuable.



## 1. Introduction

The topic of real option analysis (ROA) has undergone an explosive growth in the academic literature since Myers coined the term in a well-known 1977 article. The enthusiasm among academics about the relevance and scope of applicability of real options has, however, failed to generate a commensurate interest among practitioners.[1] Several authors argue that this is due to a disconnect between ROA academic research and the actual investment projects faced by companies[2]: on the one hand, ROA standard models, when pulled off-the-shelf from academic journals, are too stylized to capture the idiosyncrasies of applied projects; on the other hand, when ROA is used to capture in a realistic fashion the complexities and intricacies of real projects it becomes excessively cumbersome and opaque. These twin difficulties can only be surpassed by tailoring ROA analysis to the actual projects faced by companies on a case-by-case basis. That requires a careful identification of the relevant investment and operating decisions featured in individual projects – jointly with the key sources of project uncertainty – with a comprehensive mapping of their sequence and interconnections – while maintaining a concern for parsimony in what regards the number of options and the state variables considered; in other words, achieving a formulation of the problem that is realistic and, at the same time, tractable and intuitive to project managers.

In this paper we engage in a clinical analysis of an ROA application to a deep-sea offshore oil and gas exploration and production (E&P) project. Deep-sea offshore oil and gas exploration and production is a dynamic activity which is undertaken in harsh and remote environments. In addition to the engineering challenges surrounding such undertakings, the required heavy investments, accompanied with the inherent uncertainty about oil and gas prices and the volume and quality of recoverable reserves, result in large variability in the resulting economic outcomes. This risk, however, is mitigated by the high degree of flexibility that is typically featured in these projects. This flexibility – which corresponds to a portfolio of valuable investment and operating options, or real options for short – if optimally exploited, substantially improves the projects' risk-return profile.

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[1] Ryan and Ryan (2002) reports that only 10%–15% of CFOs of Fortune 1000 companies use ROA "often". A survey by Bain&Co in 2000 found that 32% of senior executives who used ROA, subsequently gave up the methodology. Surveys of CFOs such as those of Graham and Harvey (2001) and Brounen et al. (2004) find better figures for the adoption of ROA among top management.

[2] See for example Triantis (2005) and Borison (2005).

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An E&P offshore oil and gas project features many options throughout the site's life cycle. Fundamental decisions such as whether a site should be explored, what potential resources exist and their location, whether an exploration well should be carried out and which of the identified opportunities should the exploration focus on must be considered; furthermore, at some point of the field's exploration, the decision on whether to pursue further findings, to stop exploring and start the field's development phase or, yet, to abandon the project will have to be made. Moving from exploration to the development phase, will bring closure to the estimation of the volume of the findings, will enable the activities to proceed to the dimensioning of the required infrastructures for the future production phase, and will define the field's future production capacity.

Valuing and managing this range of investment and operating options is therefore critical for the success of these projects. Doing so, however, is not easy since the menu of possibly relevant options is large whereas the mathematical apparatus required to model real options gets quickly out of hand when multiple options and sources of uncertainty are considered. The latter problem is compounded by the fact that many of the real options available in upstream oil&gas projects are mutually dependent. In this paper we apply ROA to a specific deep-sea, off-shore E&P project of a medium size integrated oil&gas company, after extensively discussing with the company's Head of E&P the appropriate framework to capture the sequence of the key investment and operating decisions of the project, as well as the appropriate calibration of the project's parameters. Guaranteeing data confidentiality, we obtained typical figures for key technical and economic parameters of the project, which allows us to realistically characterize the optimal exercise rules of the featured options and estimate their value. Although project specific, the analysis illustrates many of the issues raised by the application of ROA: how technical and price state variables may be combined in a manner that captures the essence of the uncertainty faced by decision makers and is computationally tractable; how real option analysis may complement traditional Discounted Cash Flow (DCF) analysis to generate a more comprehensive and integrated view of a project; how the choice of the oil price process influences optimal decisional pathways and the value of projects' options; how some of the real options available to project managers may be unbundled into simpler but interconnected options.

Our framework consists of a sequence of exploration and appraisal options (corresponding to a succession of seismic tests and exploratory drilling activities) leading up to well delineation, finalized by a decision on whether to make an irreversible investment in a producing platform and, if the investment is made, dimensioning the scale of the platform. Once the platform has been installed, the existing reserves are extracted and sold over a 15-year period, with DCF analysis used to compute the value of the producing unit. Whereas the technical uncertainty about the amount of recoverable deposits is resolved discontinuously when exploratory and appraisal tests are performed, the oil price uncertainty is resolved continuously through a diffusion process. Concerning the oil price process we consider both a binomial tree (corresponding to a Geometric Brownian Motion (GBM) process) and a trinomial tree (corresponding to a mean-reverting process), yielding for the joint process of technical and price state variables, respectively, a quadranomial and a hexanomial tree. This approach allows for the comparison of the price trees and their implications for the exercise and valuation of the project's options.

The main conclusions of the clinical study can be summarized as follows: (i) a project that would be strongly rejected under traditional DCF analysis is accepted once the value of flexibility is accounted for; (ii) among the available options, the option to abandon is the most valuable for it allows management to exit the project in adverse scenarios such as the failure in any of the exploration phases or a large drop in the oil price, thereby avoiding costly but pointless further exploration activities as well as an irreversible investment in a loss-making platform; (iii) the value of a portfolio of real options may either be greater or smaller than the sum of the component options when the latter are valued individually. For example, the portfolio of the option to abandon the project plus the option to downsize the platform in year 3 is worth less than the sum of the individual value of the two options; in contrast, the portfolio of the option to appraise the quantity of oil in year 3 plus the option to upsize the platform in year 3 is worth more than the sum of the individual value of the two options.[3] In the former case, the whole is smaller than the sum of the parts because the component options are substitutes; in the latter, the whole is greater than the sum of the parts because they are complements; (iv) the ability of the mean-reverting oil price to incorporate information from oil futures combined with a declining oil futures curve prevailing at the initial project date yields a lower project valuation for the project under the mean-reverting oil price process; and finally, (v) the mean-reverting oil price model is more suitable to value projects with long-term cash flows linked to the oil price, as is the case of the project under analysis.

The rest of the paper is organized as follows. A brief literature review is conducted in Section 2. Section 3 presents the decision making process faced by the management team, from the initial date in which the first exploratory test is performed to an eventual irreversible investment in an operating platform. Section 4 estimates the oil price process from historical data, develops the oil price trees that map the stochastic evolution of the oil price during the project's life and explains the construction of decision trees that capture simultaneously the evolution of the two state variables – the estimate of recoverable reserves and the price of oil – and the alternative decisional pathways chosen by management. Section 5 solves the model and discusses its main results. Section 6 measures the contribution of flexibility towards project value, disaggregating the value of the various real options comprising such flexibility. Finally, Section 7 concludes.

## 2. Literature review

Tourinho (1979) was the first author to apply options theory to the development of oil reserves. Paddock et al. (1988) present the classical real options model for the analysis of upstream petroleum projects. Their model for the valuation of an offshore petroleum lease has been used as the basis for many further developments and extensions: Ekern (1988) values a marginal satellite oilfield. Bjerksund and Ekern (1990) demonstrated that for initial oilfield development purposes, where there is an option to defer the investment, it is possible to ignore the options to abandon and temporarily stop the investment. Cortazar and Schwartz (1998) apply Monte Carlo simulation to value the real options embedded in the development of an oilfield. Galli et al. (1999) analyze the application of real options, decision trees and Monte Carlo simulation in petroleum projects. Saito et al. (2001) consider several oilfield development alternatives by combining real options with reservoir simulation. Kenyon and Tompaidis (2001) study leasing contracts of offshore rigs.

One strand of the literature relevant to the current paper focuses on the option to learn new information about reservoir size and quality through exploratory and appraisal tests. Gallant et al. (1999) incorporate a learning model to deal with the complex technical uncertainty of oil projects. Chorn and Carr (1997) and Chorn and Croft (2000) assess the value of reservoir information in reducing risk in petroleum development projects. Dias (1997, 2004) explicitly models the value of learning. Bayesian updating about reservoir characteristics resulting from the exercise of learning options is used by Hatchuel and Moisdon (1997), Lund (1999) and Armstrong et al. (2004).

The effects of different oil price models on the valuation of undeveloped oil reserves are another relevant theme that has been pursued by several authors. Gibson and Schwartz (1990) suggest a two factor model in which the convenience yield follows, itself, a mean-reverting

[3] The portfolio of real options available to the project depends on what is chosen for the benchmark of the project without flexibility, an issue which is discussed in Section 6.