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INVESTIGATION OF REAL OPTIONS' INTERACTIONS: CASE OF PETROLEUM INDUSTRY PROJECT

Master's Thesis by the 2nd year student
Concentration — Master in Corporate Finance
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ЗАЯВЛЕНИЕ О САМОСТОЯТЕЛЬНОМ ХАРАКТЕРЕ ВЫПУСКНОЙ КВАЛИФИКАЦИОННОЙ РАБОТЫ

Я, Богачева Юлия Игоревна, студент 2го курса магистратуры направления 080500 - «Менеджмент», заявляю, что в моей магистерской диссертации на тему «ИССЛЕДОВАНИЕ ВЗАИМОДЕЙСТВИЯ РЕАЛЬНЫХ ОПЦИОНОВ: ПРИМЕР ПРОЕКТА НЕФТЕГАЗОВОЙ ОТРАСЛИ», представленной в ГАК для публичной защиты, не содержится элементов плагиата. Все прямые заимствования из печатных и электронных источников, а также из защищенных ранее выпускных квалификационных работ, кандидатских и докторских диссертаций имеют соответствующие ссылки.

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31.05.2017

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АННОТАЦИЯ

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Описание цели, задач и основных результатов	Целью данной работы было изучить взаимодействие реальных опционов на примере проекта нефтегазовой отрасли. В процессе работы были поставлены следующие задачи: проанализировать литературу по теме реальных опционов, их типах, взаимодействии, методах оценки; провести анализ основных стадий и рисков проектов по разработке и эксплуатации нефтегазовых месторождений; описать реальные опционы в подобных проектах; смоделировать проект по разработке и эксплуатации нефтегазового месторождения и оценить его стандартным методом NPV; идентифицировать реальные опционы в проекте и найти их количественную премию; построить и оценить портфели реальных опционов в проекте; проанализировать полученные значения и сделать выводы о взаимодействии реальных опционов внутри данного проекта. В результате подтвержден тезис о неаддитивности опционных премий. Также при включении в проект разнонаправленных опционов, таких как колл и пут, результат их взаимодействия характеризуется относительно низким негативным или даже позитивным эффектом. Более того, степень взаимодействия реальных опционов данного проекта зависит от последовательности, времени включения

	опционов в проект, а также находится ли опцион на данный момент «в деньгах» или «вне денег».
Ключевые слова	Реальные опционы, взаимодействие реальных опционов, биномиальная логарифмическая модель

ABSTRACT

Master Student's Name	Iuliia I. Bogacheva
Master Thesis Title	Investigation of Real Options' Interactions: Case of Petroleum Industry Project
Faculty	Graduate School of Management
Main field of study	080500 «Management» (Concentration: Corporate Finance)
Year	2017
Academic Advisor's Name	Anna E. Loukianova, Associate Professor, Candidate of Physics and Mathematics
Description of the goal, tasks and main results	The goal of the paper is to investigate the interaction of real options in a project for oil & gas field development. The following objectives were set in the process of work: to analyze the literature on the topic of real options, their types, interactions, methods of valuation; to carry out an analysis of the stages and risks of projects for oil & gas field exploration; to describe the real options incorporated in oil & gas field exploration project; to analyze oil and gas market; to model a project for oil & gas field exploration; to evaluate the project using the standard NPV method; to identify the real options in the project; to get a quantitative estimation of premiums for real options in the project; to build and evaluate portfolios of real options; to analyze the interactions of real options inside portfolios; to create conclusions on the interactions of real options. As a result, the statement of non-additivity of option premiums to the project was confirmed in the given project. It was also concluded that if the options are opposite, such as call and put, the result of their interaction will be most likely characterized by a relatively low negative or even positive effect. Also, the effect of the options' interactions largely depends on the level of being "in or out of the money", sequence and time, when real options are incorporated into the project given.
Keywords	Real options, real options' interactions, binomial logarithmic model

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INTRODUCTION

One of the most interesting and intensively investigated topics in modern finance is real options theory. They are really similar to their financial analogues, however, there is a real, not a financial asset, in its basis. This topic unit several scientific spheres: finance and strategic management.

Investment projects very often incorporate high level of uncertainty and managerial flexibility. Unfortunately, most of the traditional techniques, for example, NPV, is not able to take into account given characteristics. Consequently, real options methodology can be a way to solve this issue, as its application allows to model uncertainty of external environment and make managerial decisions on different stages of project implementation, and also take into account project specific risks. As a result, the most suitable areas of real options methodology application are petroleum industry, IT-projects, pharmacy, real estate projects, industries with high R&D expenses in general. Also real options can be used in leasing, outsourcing, supply chain. Unfortunately, this methodology is not that wide spread in current business practices due to complexity of mathematical procedures.

The theory of real options, its applicability to various industries, as well as the description of types, valuation methods, are covered in the papers of many foreign scientists and Russian authors, such as S. Myers, A. Dixit, P. Pindic, L. Trigeorgis, S. Black, J. Cox, S. Ross, Rubinstein, T. Copeland, V. Antikarov, E. Schwarz, S. Titman, D. Williams, L. Quigg, R. Heske, R. Agliardi, D. M. Geltner, Miller, B. Barman, K. Ye., Nash, N. Pirogov, N. Zubtsov, A. Bukhvalov and others. Majority of the current practical papers are focused on the real options' valuation in isolation, however, there are very few studies on evaluation and analysis of the options' combinations inside the project. Moreover, as a result of the existing papers' analysis, it can be concluded that, despite the high popularity of the subject, there are very few studies devoted to the evaluation of the project in the context of building a portfolio of the options.

Oil and gas field development project was chosen for the purposes of the analysis, because such projects incorporate significant risks associated with the uncertainty of oil prices and geological reserves. Moreover, it is possible to assess and manage these risks by applying the real options method. The main real options in such projects are option to delay the project, abandon or change the scope of the project.

The main research problem is the difficulty in identifying and evaluating real options and their interactions. The scientific and practical importance of research is based on the following arguments. Firstly, most projects include several real options, however, most studies are devoted to evaluating real options separately. Secondly, rise in uncertainty on the Russian market (oil prices, exchange and interest rates fluctuations) has led to the fact that the assessment process needs to take into account the increased risks. Thirdly, valuation of projects within the portfolio of real options has not been widely spread in the Russian market, and this paper can be an example for the practical application of the methodology given.

The goal of the paper is to investigate the interaction of real options in an oil & gas field development project. Thus, this paper is devoted to the problem of identifying and evaluating the combination of real options and analyzing their interactions.

The following objectives were set in the process of work:

- to analyze the literature on the topic of real options, their types, methods of valuation
- to carry out an analysis of the stages and risks of projects for oil & gas field exploration
- describe the real options incorporated in oil & gas field exploration project
- to analyze the oil and gas market
- to model a typical project for oil & gas field exploration
- to evaluate the project using the standard NPV method
- to identify the real options in the project
- to get a quantitative estimation of premiums for real options in the project
- to build and evaluate portfolios of real options
- to analyze the interactions of real options inside portfolios
- to create conclusions on the interaction of real options

The methods such as DCF method, NPV method, L. Trigeorgis logarithmic binomial model, market analysis were used in order to achieve the goals and objectives of the study.

Given paper consists of an introduction, three chapters, conclusion, list of references and appendices.

In the first chapter, the literature on the real options and their interactions, the main options' types are analyzed. The valuation methods are described, such as Black-Scholes model, Monte Carlo simulation, binomial model; and, finally, the logarithmic binomial model has been chosen to evaluate the portfolios of the real options and quantify the interactions of real options inside the portfolios.

In the second chapter, typical phases of a project to develop and operate an oil and gas field are examined in order to identify the opportunities for managerial flexibility, also the main risks of such projects are defined in order to identify the main sources of uncertainty. Real options, existing in the petroleum field development and operation projects, are described and incorporated into the project model afterwards.

In the third chapter, market analysis is conducted to identify the main market trends, which were subsequently taken into account in the financial modeling of the project and its cash flows projection. As a result, a model for the exploration and development of an oil and gas field with an NPV of 1.58 billion dollars is created. Also, three major real options in this project are described, such as an option to delay, an option to abandon and an option to expand. As a result of the valuation of real options separately, 53% premium to the gross project value for the option to defer, 10% option premium to the gross project value for the option to expand and an option premium of 6% to the gross project value to the option to abandon were obtained.

Then, the project is evaluated, taking into account various portfolios of real options. As a result, the value of the option premium is estimated as 56% of the gross project value with a portfolio of options to defer and abandon, and the result of the interaction is negative synergy of (-88) million dollars. The portfolio premium, including options to defer and expand, is estimated as 59% of the gross value of the project, and the result of the interaction is a negative synergy of (-127) million dollars. The premium to the portfolio of options to expand and abandon is 16% of the initial gross project value, and there is a positive synergy of $3 million. The size of the option premium to the portfolio of all three options is 55%, and the result of the interaction is a negative synergy of (-381) million dollars. Thus, the statement of non-additivity of option premiums to the project is confirmed. It is also concluded that if the options are opposite, the result of their interaction will be most likely characterized by a relatively low negative or, in rare cases, positive effect. Accordingly, the proposition is made that it is worthwhile to include such multidirectional real options in the projects, if there is such an opportunity. Moreover, if we consider real options as a risk management tool, the incorporation of options in the portfolio, which react differently to market changes, should improve the risk exposure indicators of the project. Also, it is concluded that the effect of the options' interactions largely depends on the level of being "in or out of the money", sequence and time, when real options are incorporated into the project.

The information sources used comprise Elsiever and EBSCO databases, Russian and foreign scientific periodicals such as "Journal of Financial and Quantitative Analysis", "Journal of Finance", "Journal of Asian Economics", "Corporate Finance", "Russian Journal of Management", national business editions of "Vedomosti", "RBC", "Delovoy Petersburg" and others.

CHAPTER 1. THEORETICAL ASPECTS OF REAL OPTIONS' METHODOLOGY

The review of the literature, devoted to the real options research topic, and the description of different empirical papers will be presented in this chapter. Afterwards the definition of real options, their portfolios and interactions will be explained, main types of options in investment projects will be described, and different real options valuation methodologies will be presented.

1.1 Definition of real options and their interactions

Option is a contract by which the owner has the right, but not the obligation, to buy (sell) underlying asset by determined price in the particular moment in the future or in the period before the expiration date. The main characteristics of the contract are expiration date and contract execution price.

Several types of the options exist. A call option is an option to buy underlying asset by the fixed price, while a put option is an option to sell. In the case of the simple call option, if the execution price is lower than the final asset price, then the option should be executed and the option price will be equal to the difference between the asset and execution price. In the other situation, if the option execution price is higher, than the option will not be executed. For the put option, the situation will be the opposite. Also, options can be divided by American and European ones, considering the execution period. American option can be executed in any time before expiration date, while European option can be executed only on the expiration date.

Moving from financial to real options, it is worth mentioning that their main difference between them is that the basic asset of the real option is a physical asset, not a financial instrument. In general, real option can be described as the opportunity to make managerial decisions, considering the uncertainty of the external environment. Interpretation of the real options parameters is presented in the table below (table 1.1.1):

Table 1.1.1. The comparison of the financial and real options parameters.

Option's Parameter	**Financial Option**	**Real Option**
Underlying asset value	Stock price	PV of expected cash flows
Execution price	Execution price	PV of investments
Period before the expiration date	Period before the expiration date	Period, when the investments can be made

Option's Parameter	Financial Option	Real Option
Volatility	Stock price volatility	Volatility of the project value
Risk-free rate	Risk-free rate	Risk-free rate

Source: Zettl M. Valuing exploration and production projects by means of option pricing theory //International Journal of Production Economics. – 2002. – V. 78. – №. 1. – P. 109-116.

The case in the paper of A. Damodaran "The Promise and Peril of Real Options" can be used for the illustration of the similarity of real and financial options. The author investigates business project characteristics and the process of project implementation as a call option. Thus, X is the sum of project investments, and V is present value of the expected cash flows. However, the company has the opportunity to postpone the project for n years, and cash flows can change under the influence of different factors. Currently, the project's net present value is negative, however, the situation can change. Making the decision about the project implementation, the company focuses on the following rule: if $V>X$, the project should be started, while if $V<X$, the project should be declined. All the initial investments will be lost in case of complete project rejection.

Using the analogy with the call option, the underlying asset is the project itself, strike price is the initial investments in the project, and the option execution period is the time period, when the company has the right to implement the project. Present value of the project's cash flows will be the value of the asset, and the fluctuations of this value will be equal to the volatility of the asset value. As a result, while calculating the value of the project with opportunity to defer, it is possible to define the value, generated by the existence of this opportunity. Finally, the option premium can be calculated from the following equation (1):

$$Option\ Premium = Expanded\ NPV - Static\ NPV, \tag{1}$$

where Option Premium - option premium, Expanded NPV- net present value with the managerial flexibility, Static NPV – net present value without the managerial flexibility.

However, there are significant differences between real and financial options. First of all, financial options are mostly contracts traded on the competitive and liquid market. Secondly, realization of real option is aimed at maximizing the asset value, while financial option is just a hedging instrument. Thirdly, the real option's owner actively participates in basic asset cash flow creation due to the possibility of managerial flexibility, while financial option cash flow is market-generated [19].

Real option's theory can be applied in case of satisfying the following conditions [27]: high level of project uncertainty which can be diminished by gathering new information in the future; management has the opportunity to make a managerial decision in case of getting new information in the future.

Modern real option's theory provides us with the methodology, which allows to evaluate the projects more accurately in the context of managerial flexibility. Myers in his paper [76] firstly introduced the term "real option". Detailed description of different types of methodology for project valuation can be found in the papers by Dixit & Pindyck [56] and Trigeorgis [93].

Also, Schwartz and Trigeorgis presented their paper [97], where real options were applied to several investment projects in order to take into account value of managerial flexibility, where traditional NPV approach could not be used. Lander and Pinches [67] marked the lack of necessary mathematical knowledge, strict model restrictions and growing complexity as main barriers to the practical implementation of the theory.

The real options' method has been applied for a long time for development and exploitation projects. The reasons are that these projects often require significant initial investment, hydrocarbons are risky and liquid assets, and management has many options to influence the project development. Tourino was the first, who evaluated the hydrocarbon reserves of the field using the real options method [88], Brenann and Schwartz analyzed the interaction of operational real options in the case of the copper deposit [44], Ekern used a real option model for estimating the deposit and evaluated the expansion option using the binomial model [57]. Siegel et al. Has assessed the option to develop the offshore field [84]. McCardle and Smith valued the option to abandon and the option to cooperate with nearby fields [85]. The price and production level were modeled as a stochastic process, where prices followed the geometric Brownian motion. Cortazar and Schwartz used the Monte Carlo model to determine the optimal time to invest in a field with an established oil recovery rate that declined exponentially [48]. Pindyck analyzed the long-term behavior of oil prices and the application of this analysis to real options [81]. Galli et al. compared the application of the real options methodology, decision tree and Monte Carlo simulation in oil production projects [58]. Lund evaluated the project for the development of a shelf field based on the case of the Severomorsk deposit "Heidrun" [69]. A dynamic programming was used in the paper, modeling the uncertainty related to the size of reserves and wells' productivity in addition to the volatility of oil prices. In the paper, the price of oil is modeled as a geometric Brownian motion, and the binomial model is used to find the optimal production volume and investment time. Dias et al. applied Monte Carlo method and non-linear optimization to find the optimal mine development strategy, while considering three mutually exclusive alternatives [55]. Chorn and Shokhor used dynamic programming and the real option method to evaluate investment opportunities related to oilfield exploration [47].

The paper of Geske [60] was one of the first papers devoted to the valuation of multiple options, which presented the instruments to evaluate compound options. However, the formula presented in given research requires significant mathematical skills. In Agliardi's article, based on the methodology provided by the previous scientist, the author suggests the way to value two sequential options to expand [32]. The same author created the analytical way for the valuation of several scaling options based on Black-Scholes model [31].

One of the first papers, based on the investigation of real options interactions, is «A Log-Transformed Binomial Numerical Analysis Method for Valuing Complex Multi-Option Investments» by L. Trigeorgis [90]. In this paper, the author defines the combination of several real options in one project as a portfolio of real options, and creates the algorithm to value this portfolio, taking into account their interactions.

Two years later, Trigeorgis in the article «The Nature of Option Interactions and the Valuation of Investments with Multiple Real Options» uses the method created previously and analyzes the valuation of the projects with portfolio of real options in detail and explain the reasons of their interactions [95]. The main statement of the paper is that the value of the real option's portfolio (multiple real option in one project) is not equal to the simple sum of the values of these options in isolation. L. Trigeorgis names the main factors, which influence the level of the options' interactions: 1) option type (for instance, call or put), 2) execution time (American or European option), 3) relative degree of «be in the or out the of money» and 4) their sequence.

In general, the reason for the interactions between real options is the fact that exercising probability for latter option in the presence of earlier real option will differ from the probability of exercising it as an isolated option.

In the paper «Evaluating Leases With Complex Operating Options» L. Trigeorgis applies his own methodology to value real options in leasing [92]. He concludes the same as in the previous papers: if the project has multiple options, the sums of options' values will be non-additive.

In the article «Project evaluation in the presence of multiple embedded real options: evidence from the Taiwan High-Speed Rail Project», authors Bowe M., Ding Lun Lee apply the same models and test the conclusions, proposed by Trigeorgis, using the case of high-speed railway in Taiwan [42]. The main advantage of this paper is that authors use real data instead of modeling. As a result, the value of the portfolio accounts for about 80% of sum of separate options values.

Among the Russian authors' papers, several articles of A. Buhvalov can be mentioned [5,6,7], which are devoted to introduction to the definition of real options, logics of their application and classification. Also N. Pirogov and N. Zubtsov published the paper "Interaction of real option in case of Russian development projects" [13]. In their paper, they consider the following types of options as option to delay, option to abandon, option to expand and option to contract.

To sum up, basing on the literature review devoted to the given research area, the following conclusions can be made:

- The topic of real options is investigated in a great number of theoretical and practical papers;
- The researchers proposed the significant amount of valuation models, several of them have become classical ones. However, most of them are complex and difficult and, consequently, are practically inapplicable;
- The several papers exist which are devoted to the identification of several real options inside the project and their valuation. Mostly, these are the papers of foreign authors, however, the only one Russian paper was found and is focused on the development industry.
- The topic of real options' interactions is almost uncovered in the literature from the viewpoint of the practical application.

1.2 Real Options' Types

The significant amount of different classifications of real options exist, depending on the underlying asset [4], balance side [17,19], type of uncertainty [19], managerial actions [11,12,16,17,18], influence on project risks [18].

In given paper, the classification of real options is presented basing on the type of managerial flexibility provided by the option, as the construction of real options will rely on the managerial decision making. These actions comprise three groups: investments and growth, delay and new knowledge, decrease in investments and abandonment. In each of these groups several options exist and are presented in the table 1.2.1. According to the following classification, seven basic option types can be identified, which can be applicable to different spheres: option to scale (increase or decrease), to renovate, to expand, to investigate, to cut costs, to decrease the diversification level.

Table 1.2.1 The options' types by A. Buhvalov.

Source of managerial flexibility	**Type of the option**	**Description**
Investments/ growth	Expansion of the scale	Expansion of the company's scale on the market in situation of the market growth and efficiency of further investments
	Product modernization	Constant technology modernization or first generation product implementation gives the advantage in move to the next product or technology generation
	Diversification	Investments in one sphere give company the opportunity to start business in the other one with lower costs
Delay/new knowledge	Investigation/start	Delay of the project till the moment the new information will be received
Decrease in investments	Decrease of scale	Scale's decrease or production abandonment, if the expected return is declining, according to the new information
	Cost reduction	Move to the less expensive, more profitable and flexible assets according to the newly received information
	Decrease in diversification level	Decrease in operations' scale or its abandonment if the given activity is unprofitable

Source: Buhvalov, A.V. Real options in management: Introduction to the problem/A. V. Buhvalov// Russian management journal. – 2004. – V. 2. – № 1. – C. 3-32.

One of the most concise classifications is proposed by L. Trigeorgis [97]. It is presented in the table 1.2.2 with insignificant additions and modifications. The following option types can be identified: option to delay, option to stage, option to expand, option to decrease, option to abandon, option to switch, timing option, multiple real options. It is worth mentioning that the earlier is the project stage, the higher is the number of real options. Moreover, considering multiple real options, their non-additive property should be pointed out, which was hypothesized and proved by L. Trigeorgis in his papers [90,95].

Table 1.2.2. The options' types by L. Trigeorgis.

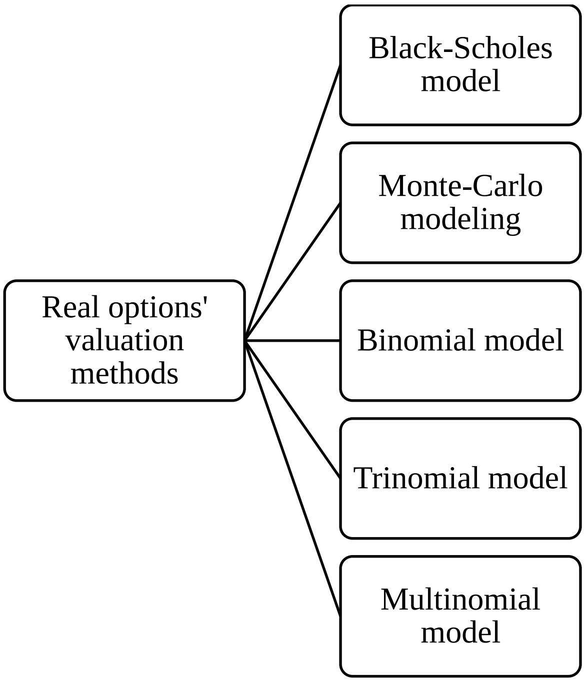
Real option	Option type	Description
Option to delay	American call-option	Management has an option to start developing the field at the moment when it starts being commercially viable.
Option to phase	Imbedded call-option	Management has the opportunity of staging project realization, deciding to continue the project on every stage, basing on the market tendencies.
Option to expand	American call-option	If market conditions have improved considerably in comparison to the planned ones, then company is able to increase the project scale by additional investments and development of supplementary fields.
Option to decrease	American put-option	If market conditions worsen significantly in comparison to the planned ones, then the company should decrease the project scale.
Option to abandon	American put-option	If market conditions worsen, the company can stop the project implementation and sell it.
Option to switch functional use	Portfolio of call and put-options	In case of price or demand change, the company can change the scope of product and services.
Timing option	American call-option	In extreme conditions the project can be stopped and renewed when the market will restore.
Multiple interacting options	Portfolio of call and put-options	Most of the projects incorporates portfolio of real options, with the additive effect is not equal to the simple sum of their independent values.

Source: Trigeorgis L., Schwartz E. S. Real Options and Investments under Uncertainty //the MIT press, London. – 2001.

2.3 Real Options' Valuation Methods

The main valuation methods applied to real options are presented in the given part of the paper. Mainly, real options' project valuation starts with the estimation of the cash flows, which can be generated by the underlying asset (DCF method). Afterwards the investment costs are incorporated (strike price) in the model, as well as value, created by the uncertainty of the asset price and flexibility of managerial decisions. Particularly, the uncertainty creates the future possibilities for the managerial flexibility, which are reflected in the option premium. As a result, the higher is the uncertainty, the higher is the option price.

The valuation of real options itself is based on the model applied to the financial options. The choice of technique depends on simplicity, availability of information and applicability to particular case. In the picture 1.3.1 the main methods of real options' estimation are presented:



Picture 1.3.1. Main approaches to real options valuation.

Source: created by the author.

One of the most famous differential equations for valuation of European non-dividend call option is Black-Scholes model, which is named in favor of the authors who published their paper in 1973 [41].

Black-Scholes equation is presented as (2):

$$\mathrm{C} = N\ (d_1)\times S_0 - N(d_2)\times X\times e^{-rt}, \tag{2}$$

where $d_1 = [\ln (S_o/X) + (r + 0.5\sigma^2)T]/\sigma\sqrt{T}$, (3)

$d_2 = d_1 - \sigma\sqrt{T}$, (4)

C – call option price,

S_0 – current price of basic asset,

X – investment costs or strike price,

r – risk-free rate,

T – time before option expiration,

σ – annual volatility of expected cash flows of the basic asset or standard deviation of natural logarithm of return on basic asset,

$N(d_1)$ and $N(d_2)$ – the value of standard normal distribution at d_1 and d_2.

This model is based on the technique of creating replicating portfolio, assumptions of the market efficiency and the absence of arbitrary opportunities.

As a result, Black-Scholes model can be used for the valuation of different assets, which have option's characteristics. However, the applicability of the given model will have multiple restrictions. Firstly, the asset can be presented as European option with particular expiration date. Secondly, the market exists for the given asset in order to create the replicating portfolio. Thirdly, it can be assumed that the basic asset return has normal distribution. Fourthly, the asset variance is constant, and, lastly, the option can be executed immediately.

Monte - Carlo modeling as one of the real options' valuation methods includes the simulation for thousands values of the basic asset prices during the life of the option.

The following input parameters are essential for the modeling:

- Current basic asset price (S_o)
- Volatility of the asset price (σ)
- Strike price (X)
- Option time period (T)
- Risk-free rate (r)
- Time step (Δt)

During simulations, the option period is divided in several stages, and thousands of simulations are conducted to identify the value of the asset on each stage. We start with the expected value of the basic asset (S_o) for each simulation in the beginning period (t = 0). In the next stage, the asset value, which can either decrease, or increase, is calculated with following equation, comprising function of random variable:

$$S_t = S_{t-1} + S_{t-1} \times \left(r \times \Delta t + \sigma \varepsilon \sqrt{\Delta t}\right), \quad (6)$$

where S_t and S_{t-1} – basic asset price in the period t and t−1 respectively; σ – volatility of the basic asset; ε – modeled value of the standard normal distribution.[1]

The value of the basic asset is calculated also in the next period with the same formula. Following this logic, the asset value is calculated till the end of the option period. Each final

[1] Mun, J. Real Options Analysis: Tools and Techniques for Valuing Strategic Investments and Decisions. – JN: John Wiley & Sons, Hoboken, 2006. – 238 p.

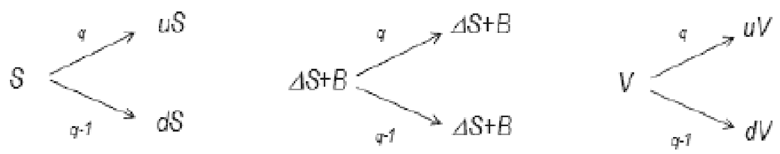
project value should be discounted by the risk-free rate, and the average of these values will be the option value of the project.

Simulations can be used easily for European options, which have fixed execution date. Option period can be divided in appropriate number of stages, and the evolution of the asset price can be modeled on each stage during the whole period. So, the higher is the number of stages and simulations, the more accurate are results.

American options, which can be executed anytime before the expiration date, suppose conduction of simulations every day inside the given timeframe, which is really time- and labor-intensive.

In 1979 J. Cox, S. Ross and M. Rubinstein created the binomial option valuation model [51]. It has several advantages over Black-Scholes model, such as possibilities to model the basic asset price changes in time, value not only European option type and incorporate inconstant variance in the model.

The model given is based on the construction of the tree, which reflects the changes in the asset price with the increasing coefficient u and decreasing coefficient d (d=1/u). The model's underlying assumption is that, if S_0 is the price of the underlying asset in the current time period, it will be equal to S_0*d with probability (1-q) and S_0*u with probability q (pic. 1.3.1) then in the moment t_1 .[2]



Picture 1.3.2. Binomial model for basic asset, replicating portfolio and option

Source: Cox J. C., Ross S. A., Rubinstein M. Option pricing: A simplified approach //Journal of financial Economics. – 1979. – V. 7. – №. 3. – P. 229-263.

Coefficients u and d are constant for each node and are calculated by the formulas (7) and (8), basing on the assumption that price change can be described by Brownian motion:

$$u = e^{\sigma\sqrt{\Delta t}}, \quad (7)$$

$$d = \frac{1}{u}, \quad (8)$$

[2] Real options and investment project in development [Electronic source]//Corporate management. – Internet project «Corporate management», [1998–2017]– Website: http://www.cfin.ru/appraisal/realty/real_options.shtml, free. – Screen title. (20.04.2017)

By the analogy with Black-Scholes model, this option valuation model is based on the creation of the replicating portfolio, which comprises *D* number of stocks with current price *S* and sum *B*, invested in risk-free bond with rate *r*.[3]

The portfolio's return replicates completely the option's return, and the following approach makes the model independent from the values of frequency probabilities q.[4] The construction of the replicating portfolio is performed in each of the lattice's nodes, except for the boundary values, where the possible option payments can be defined by the calculated value of the asset price.[5] As a result, consistently calculating the price of the option (payments) in the nodes of lattice and iterating backwards, it is possible to find necessary value — option value at the moment t_0.[6]

As there are the future values of the option payments in the basis of the current option, discounted to the current moment, then the option value can be defined by the formula (9):

$$V = \frac{qV_u + (1-q) \times V_d}{1+k} \ , \qquad (9)$$

where q — frequency probability (50%), k — risk-corrected discount rate.

The problem of this approach is that in each of the lattice's nodes is necessary to calculate the new value of the discount rate. The updated method was created in order to address the given problem, which is called risk-neutral approach, based on the risk-free rate discounting and accounted for all the risk factors with risk-neutral probability p. The value of given probability, reflecting the probability of risk-free situation occurrence, can be calculated by the formulas (10,11,12):

$$V = \left[\left(\frac{1+r-d}{u-d}\right)V_u + \left(\frac{u-(1+r)}{u-d}\right)V_d\right] \div (1+r)\ , \qquad (10)$$

$$V = \frac{pV_u + (1-p)V_d}{1+r}, \qquad (11)$$

$$p = \frac{1+r-d}{u-d}\ , \qquad (12)$$

The parameters given can be used for option value calculation in the current moment, and the values can be calculated by formula (13) in each node:

$$V_{ij} = \left[p \times V_{(i+1)j} + (1-p) \times V_{(i+1)(j+1)}\right] \div \left(1 + r_f\right). \qquad (13)$$

As a result, the option value can be found, iterating the binomial tree backward.

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[3] Real options and investment project in development [Electronic source]//Corporate management. – Internet project «Corporate management», [1998–2017]– Website: http://www.cfin.ru/appraisal/realty/real_options.shtml, free. – Screen title. (20.04.2017)
[4] Also there.
[5] Also there.
[6] Also there.

L. Trigeorgis created logarithmic binomial option pricing model for the valuation of the option portfolio [90], which will be applied in this paper, and, consequently, will be described in detail further.

Let's define V as expected value of the future project cash flows. Following the traditional methodology of real option price valuation, let's assume that the value of the basic asset V follows the Viner diffusion process. Then, in any small interval dt, $X = \ln V$ will follow the ariphmetic Brownian motion. Then in risk-neutral conditions, where $\alpha = r$ or risk-free rate:

$$dX = ln\left(\frac{V_{t+\Delta t}}{V_t}\right) = (r - 0{,}5\sigma^2)dt + \sigma \times dz \quad (14)$$

Increment dX (formula 14) is id with average $(r - 0{,}5\sigma^2)$ and variance $\sigma^2 dt$. Let's assume $k \equiv \sigma^2 dt$ to transform "time" to be identified in the units of variance, then dX is normally distributed with a mean $E(dX) = \mu k$, where $\mu = \frac{r}{\sigma^2} - 0{,}5$ and variance $Var\ (dX) = k$.

Afterwards let's divide the project implementation time *T* into *N* equal discrete intervals, each length τ $(T = N)$, and «time» step k can be approximated by $\frac{\sigma^2 T}{N}$. Inside each discrete interval τ, X will follow Markov random walk, increasing by $\Delta X = H$ with risk-neutral probability $p^+ \equiv P$ or decreasing by the same value $\Delta X = -H$ with probability $p^- = 1 - P$.

The discrete process described above can be defined in transformed node and time space. Mean (15) and variance (16) of the given discrete Markov process can be calculated as:

$$E(\Delta X) = P(+H) + (1 - P)(-H) = 2PH - H \quad (15)$$

$$Var(\Delta X) = E(\Delta X^2) - [E(\Delta X)]^2 = H^2 - [E(\Delta X)]^2 \quad (16)$$

The respective means and variances of discrete and continious diffusion processes should be equal in order to combine them. Consequently, $2PH - H = \mu k$ and $H^2 - (\mu k)^2 = k$, then:

$$P = 0{,}5\left(\frac{1+\mu k}{\mathrm{H}}\right) \quad (17)$$

$$H = \sqrt{k + (\mu k)^2} (\geq \mu k) \quad (18)$$

All the modifications created above are modeled in order to maintain the stability and consistency of discrete approximation and continious process.

According to L. Trigeorgis [90,92], almost each model can be applied in four steps: specification of the model parameters, preliminary calculations, terminal values calculation and backward iteraction of the decision tree to calculate the option value. The description of the given process is presented in the table 1.3.1:

Table 1.3.1 The algorithm of the logarithmic binomial method application.

Step 1	Define the project parameters $V, r, \sigma, T, EX's(I's), N$ Define the cash flows distribution by the time and amount
Step 2	Calculate preliminary parameters K, μ, H and P
Step 3	Define terminal project value (with $j = N$) For each node i: Project value $V(i) = e^{iH}$ Opportunity value (with imbedded options): $R(i) = \max(V(i), 0)$
Step 4	Backward iterative process: For each time interval j ($j = N, \dots \dots, 1$) and each second node i calculate opportunity value (with taking into account information from the step $j + 1$): $R'(i) = e^{-rk/\sigma^2}[PR(i+1) + (1-P)R(i-1)]$
Correction for cash flows: For cash inflows: $R'(i) = R(i - \varepsilon) + CF$ For cash outflows: $R'(i) = R(i) - I$ Correction for multiple options: At any moment of time, when option arises, option value can be calculated by the given algorithm.	

Source: Trigeorgis L. Evaluating Leases With Complex Operating Options // European Journal of Operational Research. – 1996. – No. 91. – P. 315—329.

The first step requires specification of the standard real option parameters: V, r, σ^2 and T, also dividend yield, strike price EX and costs I. Additionally, the exact amount of intervals N should be defined. For the given amount T, the higher the number of intervals N, the lower is its length and, consequently, the higher is approximation precision.

It is necessary to calculate the parameters essential for the further algorithm application on the second stage. Using the knowledge received at the first stage, the following key variables should be calculated: time step k as $\frac{\sigma^2 T}{N}$; drift μ as $(r - \delta)/\sigma^2 \times 0{,}5$; H as $\sqrt{k + (\mu k)^2}$; and risk-neutral probability P as $0{,}5(1 + \mu k/H)$.

The following remarks should be made before moving to the next stage. Let's j is integer number of the intervals of the length k, and i is integer index of the node variable, then X, in accordance with the difference of up and down movements, will be equal to $X(i) = X_0 + iH$. Then $R(i)$ will be equal to the total number of investment opportunities (project plus imbedded options) in the node i. The third stage includes the calculation of the boundary values of the terminal project values (while $j = N$). For each node i the value of the basic asset is calculated as $V(i) = e^{X_0+iH}$ (as $X \equiv \ln V = X_0 + iH$), and the final value of the investment opportunity (or expanded NPV) is calculated from the equation $R(i) = \max(V(i), 0)$.

The backward iteraction is performed with corrections for dividends and imbedded options in particular moment on the final stage. Starting with boundary values ($j = N$) and moving backwards, the calculations of the total investment opportinities values can be performed, taking into account the information from the stage $j + 1$. Consequently, the value of the opportunity $R'_j(i)$ in the earlier period j in node i between two sequential periods can be defined from the expected values of the boundary values from up and down movements, calculated at the stage $(j + 1)$ and discounted for one period of the length $\tau = k/\sigma^2$ by discount rate r (19):

$$R'_j(i) = exp\left(\frac{-rk}{\sigma^2}\right)\left[P \times R_{j+1'}(i+1) + (1-P)R_{j+1'}(i-1)\right] \quad (19)$$

As a result, it is possible to find the value of real options independently, as well as the part of the portfolio, applying the following algorithm. Consequently, while the objective of the paper is to investigate the interactions of real options inside the project basing on the creation of real options' portfolio, the given method will be the methodological basis of the analysis.

Conclusions

In this chapter, real option is defined as possibility of using managerial flexibility in the situation of external environment uncertainty. Also, the literature review is performed, and, as a result, no studies of real options interactions inside oil and gas exploration projects are identified. Moreover, the main real option types were defined such as options to change the scope of the project, to defer, to abandon, to phase, to extend the duration and multiple real options.

The main methods applied to the evaluation of real options are described: Black-Scholes model, Monte Carlo simulation, binomial model. Also, their main advantages and disadvantages are also noted. In particular, Black-Scholes model is understandable and easy to use, but it is based on fairly strict assumptions about the completeness and efficiency of the markets and is suitable only for the evaluation of European options. The binomial model allows to evaluate

American options, and it is based on the same assumptions. Modeling has its limitations also, which are mainly related to the evaluation of complex American options, as they require a significant number of simulations.

Also, within the description of the options evaluation methods, a logarithmic binomial model is described, which is used for the evaluation of real options portfolios. The algorithm for applying this methodology is presented, which consists of four main steps and is based on the project value tree construction and its adjustment for real options. Finally, the model given will be applied as a method to evaluate real options combinations and their interactions further.

CHAPTER 2. APPLICATION OF REAL OPTIONS METHODOLOGY TO PETROLEUM INDUSTRY

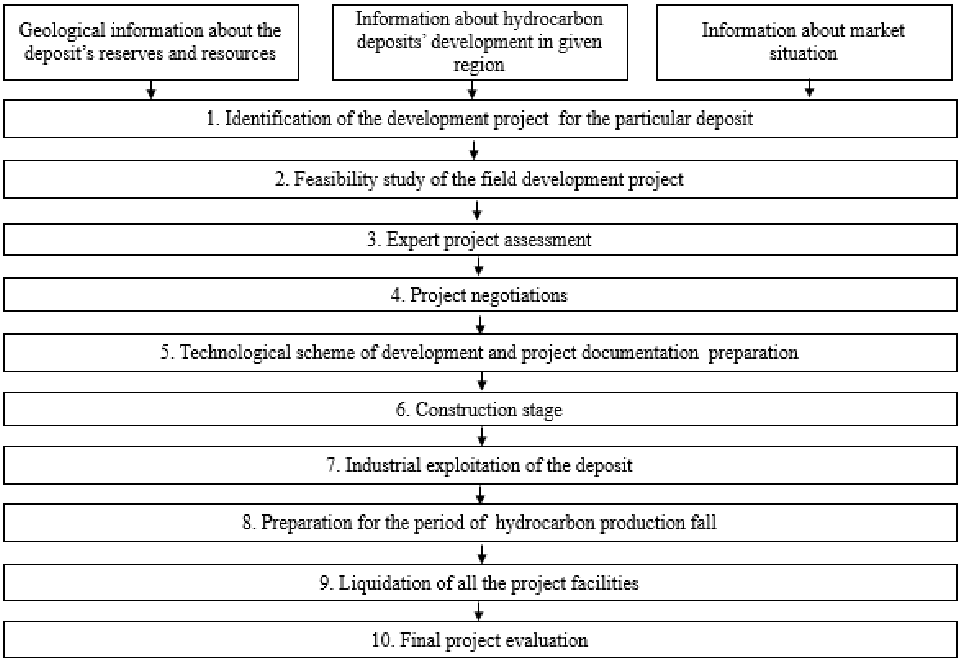
The main stages of oil and gas projects and their detailed description will be presented in the second chapter. By this, the evidence of the fact will be given that there is the opportunity for managerial flexibility during most of the project stages. Following this, the main risks and degree of their influence on the oil field exploration project will be described to define the most significant sources of uncertainty in the project. The classification of real options in petroleum industry will be presented in the last part of the chapter.

2.1 Main stages of oil & gas field production projects

In general, three main stages can be identified in the value chain for oil & gas companies: upstream, midstream and downstream. At the upstream stage, production, in-field transportation, as well as primary processing of hydrocarbon raw materials are performed. The midstream stage is intermediate and includes the product transportation along the main pipelines, delivery to the sea terminals for the oil reception, liquefied natural gas (LNG) transportation. At the downstream stage, the deep processing of hydrocarbons is carried out at oil refineries (refineries), petrochemical and LNG plants.

In this paper, the main project of the upstream stage will be considered, namely the project for the development and operation of the oil and gas field.

Figure 2.1.1 shows the designing process of the hydrocarbon deposits development. This cycle begins with the complex activities of geological exploration, calculation and approval of hydrocarbon reserves, and then the enterprise receives a license for the development of the field. Also, the feasibility study of the field development project, the technological scheme of development and the project documentation of field development is prepared. Then follows the stage of construction and installation and the beginning of the industrial exploitation of the deposit. Throughout all the project phases, the field is analyzed and a detailed development project is drawn up. At later stages, the project is prepared for the period of the hydrocarbon production fall, as well as for the liquidation of fishing and transportation facilities, land reclamation, etc.



Picture 2.1.1. The cycle of the hydrocarbon deposits development

Source: Andreev A. F., Zubareva V. D., Sarkisov A. S. Evaluation of efficiency and risks for innovative projects in petroleum industry //M.: Max Press. – 2007.

Further, the stages of the field exploitation will be considered in more detail, since the project model cash flows will be evaluated further on the basis of this information. While implementing these projects, the stages are identified on the basis of changes in the technological and economic parameters of the deposits. The current (average annual) and total oil production, the current and total production of liquid (oil and water), the water cut of the production, the current and accumulated water-oil factor, the current and accumulated water injection, oil recovery factor, number of producing and injection wells, reservoir pressure, current gas factor, average production rate, production cost productivity, labor productivity and other indicators, are assumed as the technological and economic indicators of the deposit development process.[7]

Thus, relying on the dynamics of the oil production, four main stages of exploitation can be identified.

The first stage is the development phase of the operational facility, which takes up to 4-5 years and ends with a sharp increase in oil production and has the following characteristics:

- production growth to the maximum possible level with an increase of approximately 1-2% of the balance reserves[8] of the field

[7] Fundamentals of Oil and Gas Industry [Electronic Source]// Bashneft. – Bashneft, [2010–2014]– Access mode: http://www.neftyanik-school.ru/studentam/uchebnye-kursy/course/8/29, free. – Screen title. (20.04.2017)
[8] Also there.

- production growth up to 60-80% [9]of the maximum capacity
- current oil recovery factor (approximately 10%)[10]

The second stage is the stage of maintaining a high level of production, it takes 3-7 years or more for fields with low viscous oil and only 1-2 years for high viscosity oil. This stage has the following characteristics:

- stable high level of oil production with a maximum rate of 3-17% of the deposits book value[11]
- increase in the number of wells to the maximum possible number
- current recovery factor is 30-50% and 10-15% for fields with a production peak[12]

The third stage is characterized by a significant decline in the rate of oil production and its aim is to slow this rate. This stage lasts 5-10 years or more and has the following characteristics:

- decrease in the growth rate of production by approximately 10-20% per year for low viscous oil and 3-10% for oil of high viscosity, at the end of the stage, the rate of selection is 1-2.5%[13]
- reduction in the number of wells due to watering of production and transfer of almost all wells to mechanized production
- increase in oil recovery factors at the end of the plant to 50-60% for low viscosity oil and 10-30% for oil of high viscosity[14]

These three stages are the main period of field development, and during this period about 80-90% of oil reserves[15] are extracted.

The fourth stage has the duration comparable to the duration of the previous three stages, and takes around 15-20 years[16]. It has the following characteristics:

- low and declining rates of oil extraction (on average about 1%)[17]
- total number of wells is decreasing from 40-70% of the maximum level to 10%[18]
- extraction of around 10-20% of the balance reserves of the field for the whole stage[19]

[9] Andreev A. F., Zubareva V. D., Sarkisov A. S. Evaluation of efficiency and risks for innovative projects in petroleum industry //M.: Max Press. – 2007.
[10] Also there.
[11] Fundamentals of Oil and Gas Industry [Electronic Source]// Bashneft. – Bashneft, [2010–2014]– Access mode: http://www.neftyanik-school.ru/studentam/uchebnye-kursy/course/8/29, free. – Screen title. (20.04.2017)
[12] Also there.
[13] Also there.
[14] Also there.
[15] Also there.
[16] Also there.
[17] Also there.
[18] Also there.
[19] Also there.

Thus, the subsequent building of real options will be based on the division of the development and operation process into the four stages presented above.

2.2 Risks of oil & gas production projects

There are several approaches to the definition of risk in the literature. On the one hand, it is considered only from the viewpoint of experiencing losses as a result of an undesirable event [3,10,14,21,25,30], and on the other hand, as the probability of both positive and negative deviations [8,15,17,20,29]. For the purposes of this paper, the second approach is most appropriate. In accordance with it, Meskon M., Albert M., Hedouri F. consider risk as a level of uncertainty in the prediction of the result in the "Fundamentals of Management"[20], and Lukasevich I. defines risk as a certain prognostic assessment of the possibility or consequences of a risk event [18].

It should be noted that oil and gas projects, in particular the development and operation of the fields, are highly risky due to the following factors:

- capital intensity;
- long period of implementation, which makes prediction difficult;
- existence of specific risks, such as geological, as well as an increased level of other risks (political, technological, environmental);
- high volatility in the price of energy.

The following table is a classification of the most significant risks incorporated in the development and operation of deposits at various stages of their implementation [1] (see Table 2.2.1):

Project Implementation Phase	**Risk Factor**
Preparatory stage	Remoteness of industrial centers
	Attitude of local authorities
	Availability of infrastructure
	Unconfirmed reserves
Construction	Customer's solvency

	Failure of the contractor
	Poor organization of labor contractor
	Untimely delivery
	Delays in construction
Exploitation	*Financial and economic risks*
	Demand volatility
	Tax increase
	Decrease in prices for products on the market
	Rise in construction costs
	Social risks
	Attitude of local authorities
	Insufficient level of wages
	Technological risks
	Low qualification of employees
	Insufficient reliability of technology
	Lack of capacity reserve
	Environmental risks
	The probability of volley emissions
	Harmfulness of production
	Current risk of contamination

Source: Andreyev A. F., Zubareva V. D., Sarkisov A. S. Assessment of efficiency and risks of petroleum projects: work book//M.: Maks Press. – 2007.

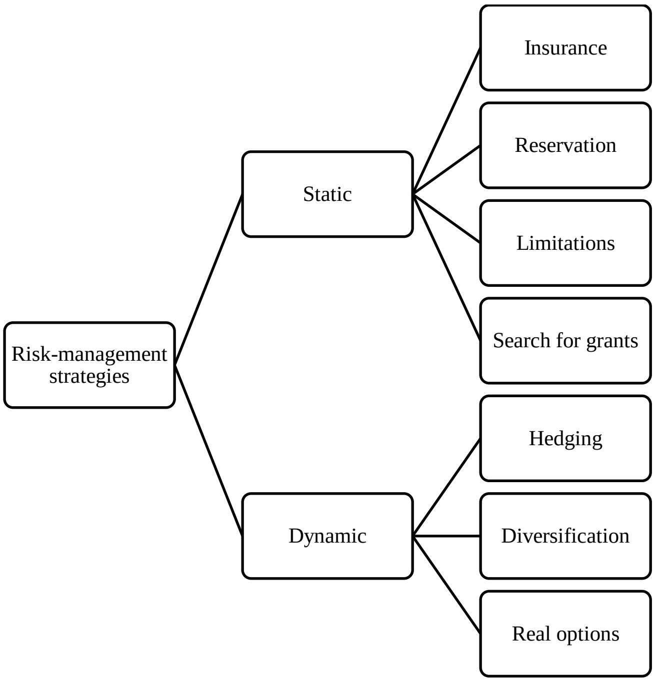
Thus, geographical factors, factor of the reserves' confirmability and availability of infrastructure are especially important at the preparatory stage. The property and production risks, financial, economic, social, technical and environmental risks come first on the operational stage.

The companies usually use the possibility of insurance, reservation, hedging, diversification, obtaining additional information, and limiting, as the main strategies for responding to emerging risks in order to prevent, transfer and reduce them.

Correct and timely application of the risk management strategies allows companies to minimize damage in the case of undesirable events, as well as take advantage of a favorable market situation for extra profit generation.

Existing methods of risk management can be divided into static and dynamic groups. Static methods assume the application of strategies that do not require active actions from the company. They are usually based on the information received at the beginning of the project implementation and do not imply management impact on the project parameters. Dynamic methods, on the other hand, require regular management involvement, which is reflected into adjusting project parameters as response actions. At the same time, dynamic methods are particularly effective for the external risks mitigation [26].

Thus, risk management strategies can be classified as follows (see Figure 2.2.2):



Picture 2.2.1. The classification of risk-management strategies.

Source: created by the author.

Static strategies include insurance, reservation, limitation, search for grants, and dynamic ones are hedging, real options and diversification of projects.

If we consider the dynamic methods in more detail, then:

- Hedging is a method that involves the transfer of risk, for example, price changes, from one subject (hedger) to another person. The contract, stating their relationship, is called hedge.
- Diversification is a method based on the distribution of investment between different, often unrelated projects in order to reduce risk and minimize possible losses.
- Real options is a method of risk management, which comprises the possibility of making flexible management decisions in the situation of external environment uncertainty. This method is implemented by building various scenarios for the development of the project and options to respond them.

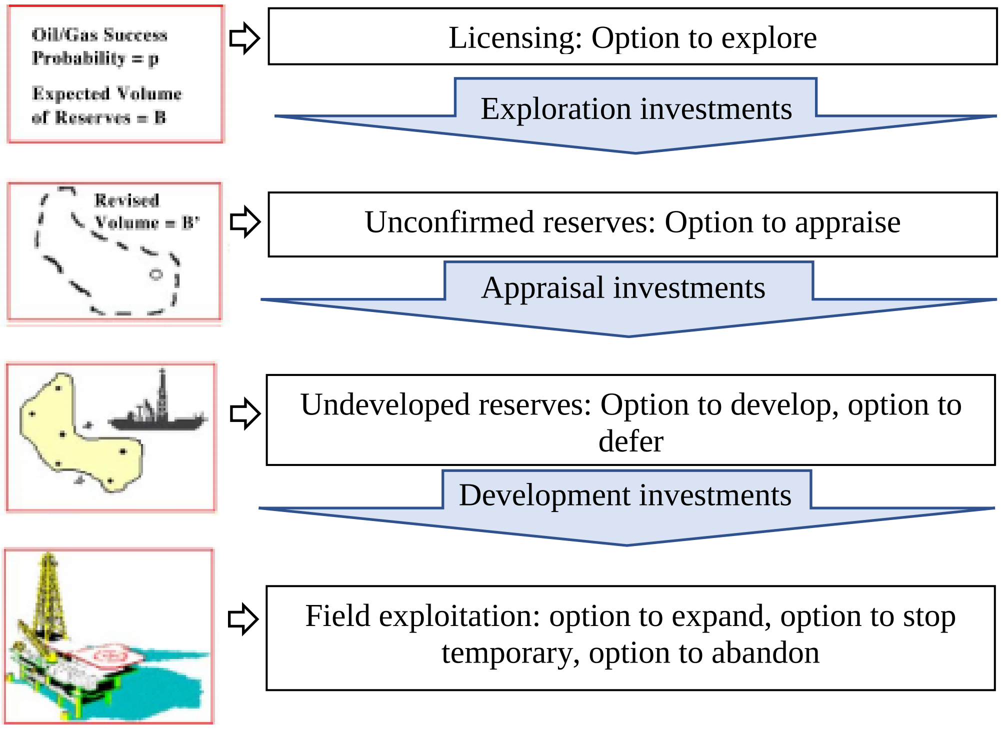
The main problem of static methods is their focus on taking into account only negative consequences, while dynamic methods allow taking into account possible positive outcomes of the risk situations. As a consequence, the dynamic methods can be more effective. Thus, the method of real options significantly increases the adaptability of the project to the conditions of the external environment and its investment attractiveness.

2.3 Types of real options in oil & gas production projects

As it was mentioned earlier, the main difference between real and financial option is that the underlying asset is a physical, not a financial asset. Also, real option models include the possibility of adoption to changing conditions, thus, giving the option holder the opportunity to influence the underlying asset value. Any action, which manager can take to adapt to uncertainty or reduce risk, is a real option.

The main sources of uncertainty in oil and gas project evaluation are prices for hydrocarbons and volumes of hydrocarbon reserves. However, the uncertainty identified can be managed at various stages of the project's life cycle, petroleum field exploration projects contain a huge number of real options.

M. Dias [54] presents a description of real options at various stages of the project for the development and operation of deposits (see Figure 2.3.1). At the preparatory stage of the project, such real options are allocated as an option for exploration, an option for valuation of reserves. At the inception stage, the option is allocated directly to the development of the field and the option to defer. At the operational stage, there is the largest number of options, among which is the option to change the scale, to stop and abandon.

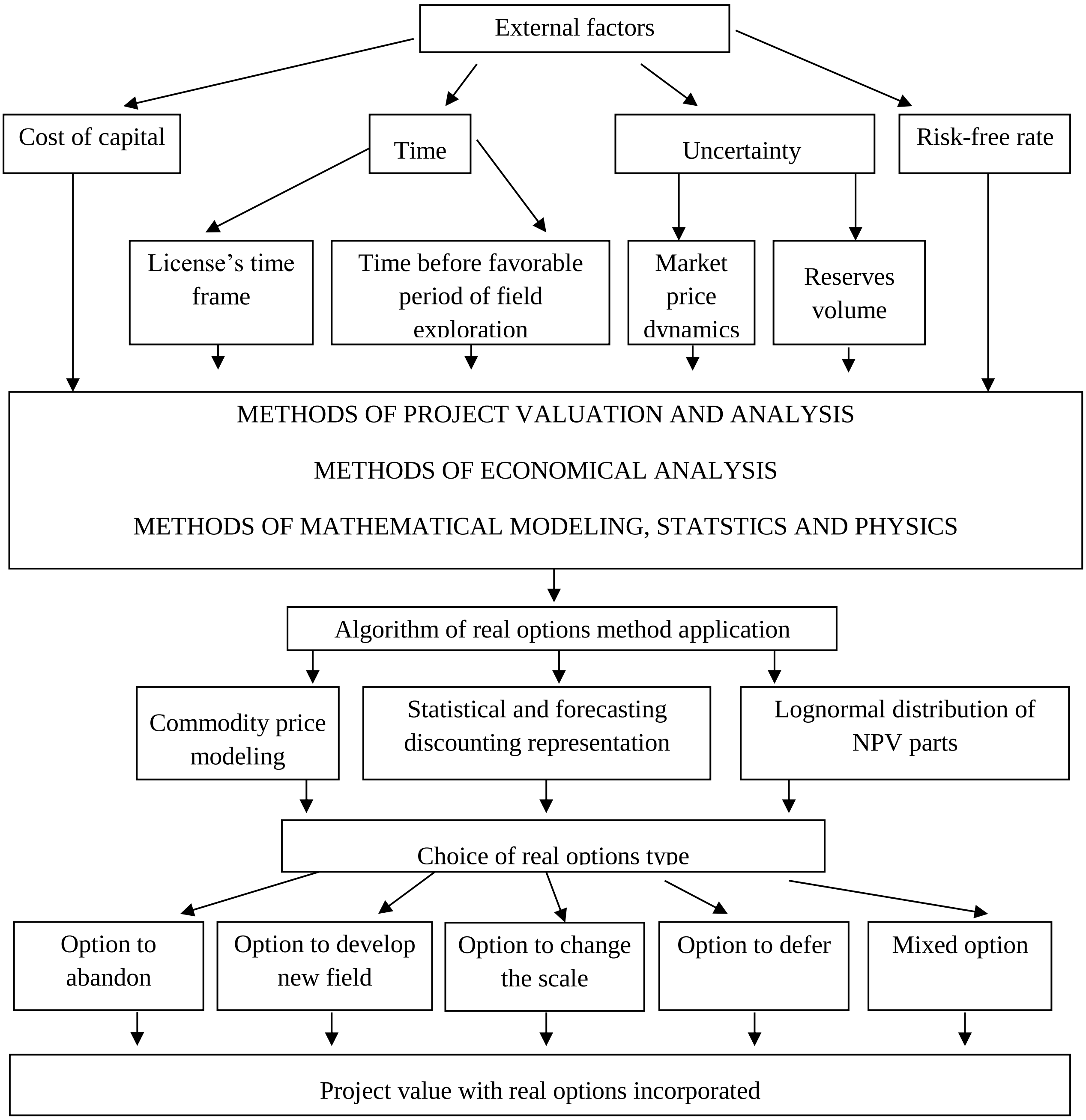


Picture 2.3.1. Field development and exploitation and real options.

Source: created by the author with the materials of Dias M. A. G. Valuation of exploration and production assets: an overview of real options models //Journal of Petroleum Science and Engineering. – 2004. – V. 44. – №. 1. – P. 93-114.

Picture 2.3.2 shows the general scheme for applying the real options method to the oil and gas sector. From this diagram, it can be seen that the external factors, influencing the project, are initially determined, in particular the cost of capital, time, source of uncertainty, risk-free rate. Then, the project is evaluated through a suitable methodology. Real options are incorporated into the project, and its value is based on the built-in options. The main options are an option to abandon the development of the field, an option to develop a new field, an option to change the scale of production, an option to delay the start of production and mixed options. Thus, in the frame of this paper, the main options are the deferral of the project, the project abandonment, the project scale change.

The option to delay the beginning of the development of the field (American call option) is the opportunity to defer the project until it becomes economically viable. In oil and gas production projects, this option should be applied taking into account that each field is licensed, and the company has a limited period of ownership of the project, which is a significant restriction for its use.



Picture 2.3.2. The application of real options to petroleum industry.

Source: Perepelitsa, D. G. Methods of analysis and efficiency evaluation of investment projects, basing on real options: thesis autoref. of can. of econ.: 08.00.05 / Perepelitsa Denis Grigorievich. —Moscow, 2009. — 23 p.

The option to abandon the exploitation of the deposit (American put option) is the opportunity to abandon the further implementation of the project, if the market situation changes in an unfavorable direction and sell the project at a market price.

The option to increase production at the field (American or European call option) is an opportunity to increase production at the field in order to extract additional profits and use economies of scale in case of a favorable market situation and available reserves.

The option to reduce production at the field (American or European put option) is an opportunity to reduce production to save part of the investment in case of an unfavorable market situation.

It is worth mentioning that all these options are often presented in projects as a combination and interact with each other, which is the subject of the further analysis.

Conclusions

Typical phases of oil and gas field exploration project are considered in order to introduce management flexibility in the investment project, namely: the preparatory stage, including exploration and evaluation of reserves, the stage of construction and development, and the stage of direct operation. The manager has the right to make managerial decisions about plans for the further project implementation at each stage.

Also, the risks of such projects are examined to determine the main sources of uncertainty. The risk of changes in oil prices and the risk of unconfirmed reserves are the strongest factors here. In addition, the financial and economic risks associated with fluctuations in exchange rates, the amount of tax payments, technical and environmental risks are high in such projects.

The key options for petroleum field development project are identified such as option to defer, option to abandon and option to change the scale.

Basing on this data, the real options will be identified further in the project model, their combinations will be constructed, and interactions will be analyzed.

CHAPTER 3. VALUATION OF REAL OPTIONS AND ANALYSIS OF THEIR INTERACTIONS IN OIL & GAS FIELD PRODUCTION PROJECT

The third chapter will present the analysis of the oil and gas market, where the main trends will be identified, which may affect the evaluation of the project. Then a financial model will be created for a project of oil & gas field development, its net present value will be calculated. Also, the real options will be incorporated in this project and evaluated, and various combinations of real options will be built, the numerical value of premiums for them will be found, and conclusions will be presented on the interaction of real options within portfolios.

3.1 Trends in oil & gas market

The oil and gas sector is one of the most important in the world economy and in Russia. For example, the oil and gas complex accounts for approximately 20% of the Russian GDP[20], 50% of the federal budget revenues[21], and 68% of foreign exchange earnings in the total export volume[22].

Russia is one of the leaders in oil production, and takes the eighth place in explored reserves level at the moment. According to the Russian Ministry of Energy, Russia's reserves are 157.1 billion tons of oil[23].

Throughout the 2000s, oil production in Russia has grown dynamically due to the intensification of production at the existing fields and the introduction of new technologies for oil recovery improvement. Most of the production is carried out on deposits discovered during the Soviet time. So, 90% is produced on the deposits opened before 1988. This situation could be explained by the fact that the majority of newly discovered reserves are located in hard-to-reach regions with severe climate conditions and the absence of infrastructure. Thus, the future rates of production growth depend largely on the ability of companies to equip quickly deposits and to accelerate the introduction of new technologies necessary to maintain production at these fields.

Also, a distinctive feature of the most of Russian deposits is the natural decline in production due to the depletion of reserves. This indicator grew significantly and reached an annual level of 11%[24] in 2000. Optimization and improvement of oil production processes contributed to the stabilization of the situation, but the rate of decline remained high. Positive dynamics of production observed after 2010 is based on the opening of new large deposits, such as the East

[20] Global trends to 2025 [Electronic source] // Lukoil. — Access mode: http://www.lukoil.com/materials/doc/documents/Global_trends_to_2025.pdf (date: 20.05.2017).
[21] Also there.
[22] Also there.
[23] Also there.
[24] Also there.

Siberian deposits of Vankor, Talakan and Verkhoechonsk. Russia should annually introduce up to 3-4 deposits comparable to Vankor to overcome the decline in production. The government issued the rights to operate the last remaining large fields registered in Rosnedra at the end of 2012. These are the Lodochnoe deposits in the Krasnoyarsk Territory and Shpilman and Imilor in the Khanty-Mansi Autonomous Area. Accordingly, the capacity of the Russian Federation to start new large fields is limited in the medium term, and the projected production volumes from new projects will not be able to maintain the natural level of production decline.

In today's conditions, oil production in Russia can be supported by increasing the level of oil recovery in existing fields, developing unconventional reserves and developing reserves of the Arctic shelf (production in this region may amount to 12 million tons[25] per year by 2025 in the current restrictions on private companies' access to the Arctic shelf). However, the state needs to create attractive conditions to develop these areas.

The global dynamics of oil prices is affected by a large number of factors, for instance, the balance of supply and demand, the macroeconomic and geopolitical situation, the dynamics of the exchange rate and the state of global financial markets.

It is also worth mentioning that the development of technology allows to begin developing of great deposits that were previously inaccessible. The growth in production of unconventional oil and gas in the US is a real example of this. Taking into account this trend, many analytical agencies decrease their long-term forecasts of oil prices. At the same time, factors such as urbanization, population growth, rising costs of exploration and production, and policies of the OPEC countries are the drivers of oil prices increase.

The human population continues to grow rapidly, so it has increased by an average of 1.1 billion people[26] from 2010 to 2015. The most significant growth will occur in developing countries, while the population of developed countries will remain relatively constant. High population growth rates will be observed in India, which will become the most populated country by 2020. Significant population growth is also projected in the African region, but it will be the result of improvement in social and economic conditions and increase in level of medical services. There will be a tendency towards urbanization simultaneously with the population growth in developing countries. According to the McInnelligence Institute, 440 cities in developing countries will generate up to half of the world's GDP by 2025.[27] Consequently, it is expected that the urban

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[25] Global trends to 2025 [Electronic source] // Lukoil. — Access mode: http://www.lukoil.com/materials/doc/documents/Global_trends_to_2025.pdf (date: 20.05.2017).

[26] Annual Energy Outlook 2017 with projections to 2040 [Electronic resource] // U. S. Energy Information and Administration. — Access mode: http://www.eia.gov/forecasts/aeo/pdf/0383(2017).pdf (date: 20.05.2017).

[27] Global trends to 2025 [Electronic source] // Lukoil. — Access mode: http://www.lukoil.com/materials/doc/documents/Global_trends_to_2025.pdf (date: 20.05.2017).

consumer class will increase to 1 billion people by 2025 and will account for 50% of the total world population[28]. A significant increase in the number of cars is expected and the growth of sea, air and rail transport. The motorization of the developing countries population is another fundamental factor for the future growth of oil demand. Currently, developing countries are significantly behind the developed by the number of vehicles per thousand people, which creates the basis for a significant increase in the vehicles ownership volume. The most noticeable changes in the ownership of cars will be observed in China, whose car market has already entered a phase of active growth. At the moment, the number of cars per thousand people is 40, but by 2025 this figure will reach 220, which means a growth of 220 million cars in the period from 2010 to 2025[29]. This trend is also observed in India and other developing countries. And by 2025, large-scale growth will begin in Africa. Generally, aggregate growth in the transport sector will contribute to an increase in fuel consumption by 9 million barrels per day by 2025. All these changes will contribute to the demand growth for the real estate, infrastructure, transport sectors, high-tech industries. Moreover, the petrochemical industry will also contribute to the demand growth for oil. The demand for liquid hydrocarbons will continue to grow at the rate of 1.2% per year and, according to Lukoil estimates, will reach 105 million barrels by 2025[30].

At the same time, consumption of liquid hydrocarbons in developed countries will remain relatively stable due to low economic growth rates and further optimization of fuel economy. Despite stable growth rates, the share of oil in world consumption of energy resources will gradually decrease due to substitution of other types of energy resources, for example, gas, in such sectors as energy, housing and communal services.

At the moment, there is a trend of reducing fuel consumption by passenger cars, which is due to many reasons, in particular design, engine improvement, fuel quality; also, hybrid technologies are becoming more common. However, in the next decade, internal combustion engines will dominate. In general, fuel reduction will be progressive and can reach 30% by 2025.[31]

The last decade has been characterized by an unprecedented increase in exploration and production costs. According to the latest estimates, companies' expenses for geological exploration, infrastructure development and production have more than tripled since the beginning of the century. This is largely due to the depletion of the existing traditional resource base. The growing demand for hydrocarbons motivated the company to develop unconventional and

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[28] Annual Energy Outlook 2017 with projections to 2040 [Electronic resource] // U. S. Energy Information and Administration. — Access mode: http://www.eia.gov/forecasts/aeo/pdf/0383(2017).pdf (date: 20.05.2017).

[29] Also there.

[30] Global trends to 2025 [Electronic source] // Lukoil. — Access mode: http://www.lukoil.com/materials/doc/documents/Global_trends_to_2025.pdf (date: 20.05.2017).

[31] Annual Energy Outlook 2017 with projections to 2040 [Electronic resource] // U. S. Energy Information and Administration. — Access mode: http://www.eia.gov/forecasts/aeo/pdf/0383(2017).pdf (date: 20.05.2017).

expensive fields. Currently, about 15 million barrels a day from the world production has a production cost of more than $70 per barrel[32]. For example, shale oil in America, on average, has a cost price of $80 per barrel. So, it can be concluded that even if the demand for oil falls significantly, its equilibrium price is unlikely to be below 70-80 dollars per barrel in the long term.[33]At the same time, production growth will be secured in the future through the development and extraction of non-traditional deposits such as the deep-water shelf, heavy oil from Canada, Venezuela and others.

Also, the spread of GTL (gas-to-liquid) technology can be a challenge for the oil market after 2020. This technology implies conversion of natural gas into sulfur-free motor fuels and other high quality hydrocarbon products. At the moment, there are only a few plants working on this technology, such as Pearl GTL and Escravos GTL in Nigeria. However, technologies are already beginning to appear, which can help to reduce the capital costs for the construction of similar plants and significantly affect the narrowing of the spread between the prices of oil and gas.

Russia also has the greatest proven natural gas reserves in the world. Most of them (more than 60%[34]) are in Western Siberia. The geological and technological conditions of this region are well known, and the current reserves will last for almost a century. At the moment, companies are gradually beginning to develop Eastern Siberian deposits and continental shelf. The resource potential for natural gas production is sufficient to cover both domestic and export demand. Natural gas is about half of all primary energy resources consumed in Russia. The level of consumption has stabilized in Russia, and it is likely to show minimal growth in the medium term. In many respects, it is the result of energy efficiency improvement and slowing pace of industrial growth. Gazprom, operating through a single gas transportation system, remains the main player in the Russian gas market. However, more flexible, independent gas producers have also taken their market share of 30% over the past few years, and now the market has becoming an oligopoly from the monopoly structure. Gazprom has a monopoly on gas exports currently. Other manufacturers and government officials are actively discussing the possibility of a gradual abolition of the export monopoly, starting with LNG projects.

The main factors for the demand growth for gas, which was originally considered as a by-side product in the extraction of oil, are relative environmental friendliness (reduced CO2 emissions into the atmosphere) and low costs compared to other types of fuel commodities. Gas power plants replace traditional coal and oil in Asia and Middle East. Gas consumption will also

[32] Global trends to 2025 [Electronic source] // Lukoil. — Access mode: http://www.lukoil.com/materials/doc/documents/Global_trends_to_2025.pdf (date: 20.05.2017).
[33] Also there.
[34] Also there.

continue to grow in North America, but China will be the main consuming region. According to Lukoil estimates, until 2025 global gas consumption will grow at the average annual growth rate of 2.2%[35].

At the beginning of the century, the three major gas markets (US, Southeast Asia and Europe) faced stagnant local production along with rising demand for gas, which allowed suppliers to dictate their terms. The main pricing principle was long-term indexed contracts, where the price of gas was determined based on the cost of alternative fuel, for example, oil. Long-term contracts, as well as the "take-or-pay" principle, were justified by the need of the sources for investments. Gas was supplied mainly through pipelines, and the scale of the liquefied natural gas market was limited. By the end of 2000s, the situation had changed. Technological innovations allowed the development of significant reserves of shale gas in the United States. Intensification of deposits development has led to the discovery of new promising regions with significant reserves around the world. Also, in recent years, the capacity of LNG projects has almost doubled. There was also drop in demand due to the global economic crisis, growing supply, increase in the trading volume in gas contracts in financial markets. As a result of all these trends, consumers began to set their requirements on the international gas market.

In general, unconventional gas projects, such as shale gas, will gain popularity. So, US can become net exporters of gas by 2020 due to these projects. Also, these deposits can be developed in Latin America and Asia. China, which has the most favorable conditions for the development of shale deposits, has already started importing the necessary technologies. However, factors such as lack of necessary skills, lack of water resources, can limit the development of these reserves. Moreover, with the development of non-traditional deposits, large reserves of traditional gas are discovered in South-East Africa and the Eastern Mediterranean.

Thus, the main trends of the world oil and gas market will be summarized below:

- Demand for liquid hydrocarbons will grow, as the increase in population and consumer class in Asia will contribute to this growth, and the main driver will be the development of the transport sector in developing countries.
- The growth in oil production in North America should not lead to a collapse in world oil prices, since modern methods for estimating shale reserves include considerable uncertainty. Many factors, such as the growing costs of reserves exploration, the balancing role of OPEC, can help maintain oil prices at the appropriate level in the long term.

[35] Global trends to 2025 [Electronic source] // Lukoil. — Access mode: http://www.lukoil.com/materials/doc/documents/Global_trends_to_2025.pdf (date: 20.05.2017).

- European oil industry is experiencing a systemic crisis due to emerging trends, such as lower imports of US fuel and the creation of new highly efficient oil refineries in the Middle East and Asia.
- Gas consumption will grow faster than oil consumption, and China will have the main growth potential of gas consumption, while the European market, which is a traditional client of Russia, will continue to stagnate.
- Large-scale investments in new technologies are required to maintain production levels in Russia. The projects currently planned are not able to compensate the decline in the production of current deposits, which, without significant investments, may begin as early as 2016-2017.
- The main challenge for the Russian gas industry will be to gain access to new growing markets due to the fact that competition in global gas markets will continue to grow.

3.2. Valuation of oil & gas field exploration project with NPV method

This part of the work will propose a financial model for the project to develop and operate a traditional oil and gas field. It is assumed that the field will produce oil and associated gas condensate. The oil reserves will amount to 90 million tons with the expected production of 70 million tons (or 650 million barrels of oil), while gas production will be 35 billion cubic meters.

The project implementation period will be 31 years and will consist of the following phases (see Table 3.2.1):

Table.3.2.1 Phases of the project development and operation

Stage	Duration	Description
Preparatory stage	4 years	Evaluation drilling, preparation of necessary infrastructure
Development of the operational facility	4 years	Beginning of production and its build-up to maximum levels by the end of the period
Stage of maintaining a high level of production	4 years	High level of production, approximately 10% of the book value of inventories
Decrease in production rates	5 years	The production level is reduced from 8% to 4% of the balance reserves for the period
Final stage	13 years	The period of development of the remaining 20% of the deposits with a fall to 1% by the end of the period

Source: created by the author.

Next, the structure of the project's cash flows will be discussed in detail, namely the annual volume of production and prices for energy carriers, depreciation, net working capital, capital expenditure structure, and taxes.

On the charts 3.2.1 and 3.2.2. The structure of oil and gas production in accordance with the stages outlined above is presented:

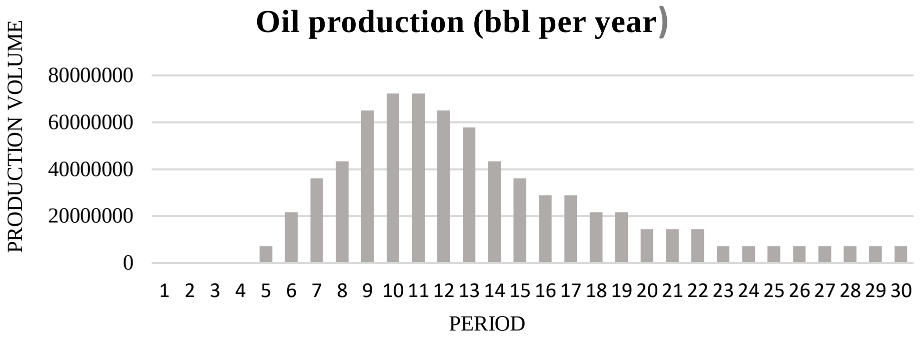

Figure 3.2.1. Oil production (bbl per year)

Source: created by the author.

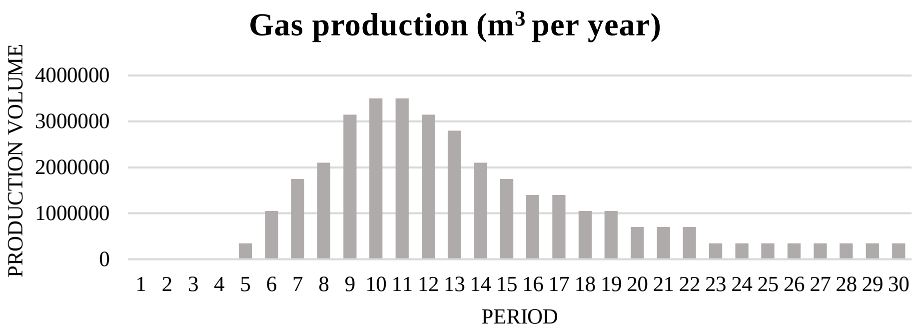

Figure 3.2.2. Gas production (m^3 per year)

Source: created by the author.

Table 3.2.3 presents energy prices from the annual EIA report [34], which were used in forecasting revenues:

Table 3.2.3. The cost of oil and gas in prices in 2016.

Energy resources prices in 2016 values (USD)	2020	2025	2030	2035	2040	2045
Oil price ($ per bbl)	74,82	86,23	94,52	102,15	109,37	112,01
Gas price ($ per thousand m^3)	4,51	4,51	5,00	5,09	5,07	5,43

Source: Annual Energy Outlook 2017 with projections to 2040 [Electronic resource] // U. S. Energy Information and Administration. — Access mode: http://www.eia.gov/forecasts/aeo/pdf/0383(2017).pdf (date: 20.05.2017).

The revenue structure is shown in Appendix 1.

In the framework of this project, it is assumed that oil and gas being developed at this field are oriented to both the domestic market and for export. As a result of the analysis of the reports of Russian oil companies such as Lukoil, Rosneft, Gazprom Neft, Tatneft, Surgutneftegaz, it was revealed that the export duty is approximately 30% of the revenue, and the remaining taxes are an average of 17% of the company's revenues. These data were used to forecast cash flows for these items. As part of the project evaluation, the profit tax was assumed equal to 20%.

For the purposes of valuation, a linear method for calculating depreciation was applied, and on average it amounted to 3.5% of the total sum of capital investments.

Working capital was taken as 3.91%[36] of the revenue of the corresponding period, according to the data on the ratio of working capital and revenue for companies operating in the sector of development and exploitation of oil and gas fields in the emerging markets.

Overall operating costs include 1) the costs of operation and maintenance of commercial facilities, wells, taken equal to 4% of the total cost of commercial items and drilling (according to similar projects)[37], 2) operating costs and maintenance of pipelines and terminals assumed equal to 2% of the total sum of investments in pipelines and terminal (according to similar projects), 3) depreciation, production costs assumed equal to $ 4 per barrel[38], 4) as well as the liquidation costs of the field are estimated as 10% [39] of the total capital cost by methodology used in SC "Gazprom".

Calculation of taxes, depreciation, general operating costs, etc. is presented in Appendix 2 and 4.

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[36] Working capital ratios by sector [Electronic source] // A. Damodaran. — Access mode: http://people.stern.nyu.edu/adamodar/New_Home_Page/dtafile/wcdata. (date: 20.05.2017).

[37] Retrospective valuation of oil company: Vankor field case [Electronic source]// Samara State Technical University. – Access mode: http://vestnik.samgtu.ru/uploads/series/1/17/136/2013-1-7-0008.pdf (date: 20.05.2017).

[38] Retrospective valuation of oil company: Vankor field case [Electronic source]// Samara State Technical University. – Access mode: http://vestnik.samgtu.ru/uploads/series/1/17/136/2013-1-7-0008.pdf (date: 20.05.2017).

[39] About liquidation funds creation [Electronic source] // Petroleum geology. — Access mode: http://www.ngtp.ru/rub/3/9_2010.pdf (date: 20.05.2017).

The capital costs include project expenses for drilling, building of infrastructure, central oil platform, preparation of wells, external oil and gas pipelines, construction of the terminal. The structure of capital expenditures is presented in Figure 3.2.3:

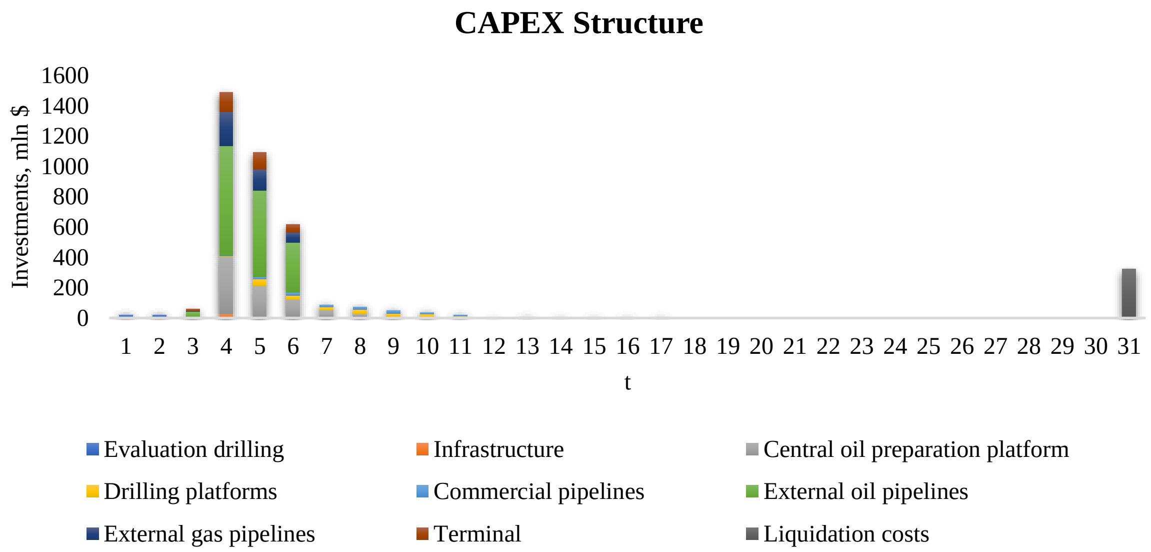

Figure 3.2.3. Structure of the CAPEX project.

Source: created by the author.

The amount of capital expenditures were extracted from the feasibility studies of projects of this type, in particular the Vankor field[40]. Calculation of capital expenditures is presented in Appendix 3.

Based on the input data described above, project cash flows have been projected by FCF method:

$$FCF = EBIT \times (1 - t) + Depreciation - CAPEX - Net\ working\ capital, \quad (20)$$

where FCF – free cash flow,

EBIT – earnings before interest and taxes,

CAPEX – capital expenditures,

t – tax rate.

Cash flows were projected in real values and denominated in US dollars.

The discount rate was determined by the WACC model in accordance with the formula (21):

$$WACC = k_d \times (1 - t) \times w_d + k_p \times w_p + k_s \times w_s\ , \quad (21)$$

[40] Retrospective valuation of oil company: Vankor field case [Electronic source]// Samara State Technical University. – Access mode: http://vestnik.samgtu.ru/uploads/series/1/17/136/2013-1-7-0008.pdf (date: 20.05.2017).

where: k_d - cost of debt; t_c – profit tax rate; w_d – debt portion in capital structure; k_p - cost of equity (privileged shares); w_p - equity portion in capital structure (privileged shares); k_s - cost of equity (ordinary shares); w_s - equity portion in capital structure (ordinary shares).

Initially, the rate of return on equity was determined using the CAPM model (22):

$$R = R_f + \beta \times (R_m - R_f) + S_1 + S_2 + C \ , \qquad (22)$$

where: R – required return on equity; R_f – risk-free rate; R_m – market return; β – beta coefficient; S_1 – premium for small enterprises; S_2 – premium for company risk; C – country risk premium.

A dollar rate for Eurobonds Russia-2042 of 4.69%[41] was accepted as risk-free rate, due to the fact that the project implementation period is 31 years. As premium for the risk of the developed market, the US risk premium was used equal to 5.51%[42], adjusted for the ratio of the standard deviation of the RTS index (26.23%) and the S&P index (16.89%) to take into account the sovereign risk of the Russian Federation. Beta indicators, capital structure and cost of debt were determined based on average market data for companies performing in the development and exploitation of oil and gas deposits on emerging markets. Russian average market indicators were not used, as large vertically integrated oil and gas companies operate in multiple businesses, including oil refining, petroleum products processing, transportation businesses that have slightly different risks. Thus, the beta coefficient of companies involved in the development and operation of fields, is 1.47[43], and the ratio of debt to equity D / E is 42.57%[44]. The tax rate is 20%[45]. The rate of return on equity of the company by the CAPM model (see formula 22) was 21.54%. The cost of debt was taken as 5.58%[46], as the cost of debt of companies involved in the same activities. As a result, the calculation of the weighted average cost of capital is presented in Table 3.2.2:

[41] Government bonds [Electronic source]// Rusbonds. Interfax Goup. – IA «Finam», [2004–2017]– Access mode: www.rusbonds.ru/cmngos.asp, free. – Screen title (20.04.2017)
[42] Damodaran A. Investment Evaluation: Tools and Methods for Valuation of any Assets / Asvat Damodaran. - 5th ed. - M.: Alpina Business Books, 2008. - 649 p.
[43] Betas by sector [Electronic resource] // A. Damodaran. — Access mode: http://pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/Betas.html (date: 20.05.2017).
[44] Cost of capital by sector [Electronic resource] // A. Damodaran. — Access mode: http://pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/wacc.html.htm (date: 20.05.2017).
[45] Profit Tax [Electronic source]// Federal Tax Services, - FNS Russia, [2005–2017]– Access mode: https://www.nalog.ru/rn77/taxation/taxes/profitul/ (date: 20.05.2017).
[46] Cost of capital by sector [Electronic resource] // A. Damodaran. — Access mode: http://pages.stern.nyu.edu/~adamodar/New_Home_Page/datafile/wacc.html.htm (date: 20.05.2017).

Table 3.2.2. Calculation of the discount rate for the WACC model.

Parameter	Value
Beta	1,47
Risk-free rate	4,69%
Risk premium for developed market	5,51%
SD RTS	0,29
SD S&P	0,17
ROE	21,54%
D/E	42,57%
Cost of debt	5,58%
Tax rate	20%
WACC	**16,44%**

Source: created by the author.

As a result, WACC amounted to 16.44%, this value was accepted for the discount rate of the project's cash flows.

Thus, the NPV of the project was calculated according to the formula:

$$NPV_0 = \sum_{t=1}^{n} \frac{CFO_t}{(1+i)^t} - \sum_{t=1}^{n} \frac{I_t}{(1+i)^t} = V - I_o = 3{,}29-1{,}71=1{,}58 \text{ bln } \$.$$

A detailed calculation is presented in Appendix X.

This value of 1,58 billion dollars and will subsequently be the starting point for further calculations.

The sensitivity of the project to the main risk factors, such as the level of reserves and the level of prices for hydrocarbons, was also analyzed. The change in these factors was studied in the range from + 50% to (-50%). The results of the analysis are shown in graph 3.2.4:

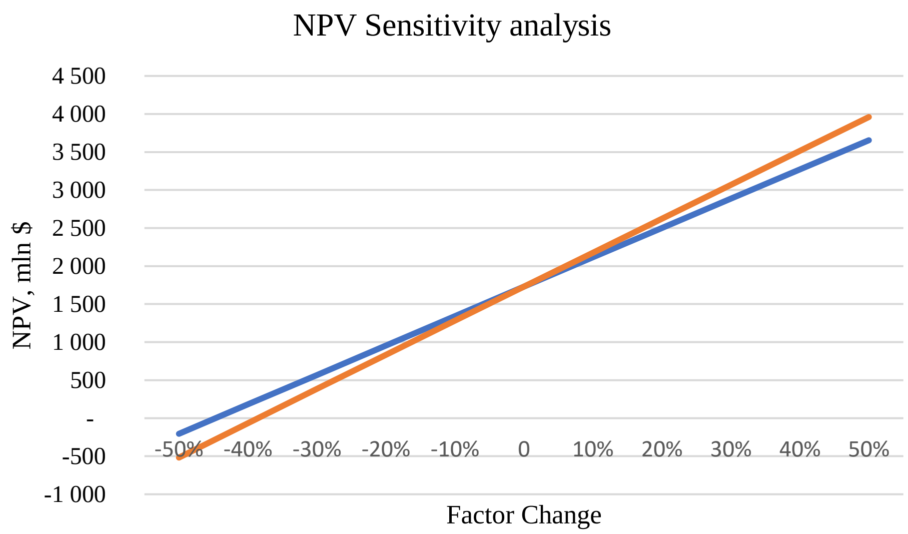

Figure 3.2.4. NPV sensitivity analysis.

Source: created by the author.

Basing on the sensitivity analysis, it can be concluded that the net present value of this project is negative in the case of a 40% decrease in hydrocarbon prices and 45% in reserves. Such results are observed due to the fact that, in general, the cost of oil production in Russia is low, about $12 per barrel[47], and therefore even with significant changes in revenue indicators such a cost level ensures profitability of production. However, if this was not a project to develop conventional oil reserves, but other fields, the cost would be much higher and the sensitivity of the project would be also more significant.

3.3. Valuation and analysis of real options and their interaction in oil & gas field exploration project

In order to apply the real options method, the following options have been identified in this project: an option to defer the project, an option to expand and an option to abandon the project.

Option to defer. The option to defer field development can be considered as an American call option. At the same time, the present value of the project (V) is considered as a basic asset, and the exercise price is the present value of the necessary investments that needed to be made for the implementation of the project with deferral (X). The value of the deferral option is $max\ [V - X; 0]$. The option period is 2 years. It is assumed that after the second year and making the appraisal drilling, in the case of an unfavorable market situation and low oil prices, the company will be able to postpone the actual implementation of the project for one year, when the

[47] Global trends to 2025 [Electronic source] // Lukoil. — Access mode: http://www.lukoil.com/materials/doc/documents/Global_trends_to_2025.pdf (date: 20.05.2017).

market situation will become more favorable. The term of the option was limited to two years and the possible delay is 1 year because the company receives a license to develop the field, and any delay of the project reduces the period of possible field operation. In this paper, the time step is equal to a year. In general, the model [90] includes dividend income, as a characteristic of the project options. However, for the purposes of this paper, the project for the development and operation of the field is considered as a non-dividend project with a correction of the project cost for only multiple options. As a risk-free rate, the yield to maturity of state Eurobonds Russia-2020 equal to 2.49%[48] was accepted. Then, in accordance with formulas (17,18), the parameters k, μ, H, P were calculated:

Time step, k:	$k = {\sigma^2 \times T}/{N} = 0{,}1343$
Drift, μ:	$\mu = {r}/{\sigma^2} - 0{,}5 = -0{,}3146$
Coefficient, H:	$H = \sqrt{k + (\mu k)^2} = 0{,}3689$
Probability, P :	$P = 0{,}5\left(1 + {\mu k}/{H}\right) = 0{,}4427$

A method based on historical data was applied in order to calculate the volatility of the project. The barrel price of Brent crude oil was chosen as a basis for volatility estimation. Thus, a sample of 6,664 daily oil price values was unloaded from September 20, 1990 to December 31, 2016.

On the basis of these data, the coefficient u_i was calculated according to the formula (23):

$$u_i = ln\left(\frac{S_n}{S_{n-1}}\right), \text{ where i=1,2,…,n} \quad (23)$$

Then, the standard deviation estimate u_i (24) was found:

$$s = \sqrt{\frac{1}{n-1}\sum_{i=1}^{n}(u_i - \bar{u})^2} \quad (24)$$

where s – standard deviation, n – number of observations, $\bar{u}$ - average of u_i. As a result, a daily standard deviation of 2.29% was obtained.

However, the intervals in simulation are years, respectively, according to the formula (25):

$$\sigma_{per} = \sigma_{day} \times \sqrt{\tau_{per}}, \quad (25)$$

[48] Government bonds [Electronic source]// Rusbonds. Interfax Goup. – IA «Finam», [2004–2017]– Access mode: www.rusbonds.ru/cmngos.asp, free. – Screen title (20.04.2017).

where σ_{per}- price volatility in the given period, σ_{day}- daily volatility, τ_{per}- number of days in the period.

Thus, taking a period of one year with on average 257 traded days, a value of σ_{per} = 35.65% was obtained. However, in this model, a variance is used as a measure of volatility, which accordingly amounted to 13.43%. This value will be used to calculate the value of subsequent options.

In table 3.3.1. the values of all option parameters are presented:

Table 3.3.1. Parameters of the option to defer the project.

Parameter	Value
Project value, V (mln $)	3 297
Exercise price, S (mln $)	1 714
Option period	2
Variance	13,43%
Risk-free rate	2,49%
Number of intervals	2
Time step, k	0,1343
Drift, m	-0,3146
Coefficient, H	0,3689
Probability, P	0,4427
Option value, (mln $)	1 746

Source: created by the author.

Then, in accordance with the algorithm and the model proposed by L. Trigeorigs [90], the value tree was constructed, which, when the option occurred, was corrected in accordance with the rule: $R' = max\left(e^{-rt}E\left(R_{j+1}\right), R_j\right)$. The calculation is presented in Appendix 5.

Thus, the NPV of the project, taking into account the option to defer, amounted to $ 3.29 billion, and the value of the option to defer the project is $ 1.7 billion or 52% of the gross value of the project.

Option to abandon. It is assumed that it is possible to sell the field and the relevant infrastructure during the first 10 years of the project. This can happen if, for example, a company concludes that the project is not suitable to the portfolio of its assets, there are currently unfavorable market conditions or the company needs cash. Thus, the company can absorb its losses. The option to stop the development of the field can be considered as an American put option.

The present value of the project (V) is considered as the basic asset, and the exercise price will be the cost of the field sale, which in this case is equal to the sum of the capital costs for the period of the option (A). The value of the abandonment option is $max\ [A - V; 0]$.

The option period is 10 years. The period of 10 years is chosen because the company for this time period still does not explore most of the reserves and the sale of the deposit will make sense. As a risk-free rate, the yield to maturity of state Eurobonds Russia-2028 was equal to 3.95%[49]. Variance of the project was 13.43%. Then, in accordance with formulas (17,18), the parameters k, μ, H, P were calculated:

Time step, k: $k = \sigma^2 \times T / N = 0{,}1343$

Drift, μ: $\mu = r / \sigma^2 - 0{,}5 = -0{,}2059$

Coefficient, H: $H = \sqrt{k + (\mu k)^2} = 0{,}3675$

Probability, P : $P = 0{,}5\left(1 + \mu k / H\right) = 0{,}4624$

In Table 3.3.2. the values of all option parameters are presented:

Table 3.3.2. Parameters of the option to abandon the project.

Parameter	**Value**
Project value, V (mln $)	3 297
Exercise price, S (mln $)	1 676
Option period	10
Variance	13,43%
Risk-free rate	3,95%
Number of intervals	10
Time step, k	0,1343

[49] Government bonds [Electronic source]// Rusbonds. Interfax Goup. – IA «Finam», [2004–2017]– Access mode: www.rusbonds.ru/cmngos.asp, free. – Screen title (20.04.2017).

Drift, m	-0,2059
Coefficient, H	0,3675
Probability, P	0,4624
Option value, (mln $)	183

Source: created by the author.

Then, in accordance with the algorithm and the model proposed by L. Trigeorigs [90], value tree was built, which, when the option occurred, was adjusted, according to the rule: $R' = max(R, A)$. The calculation is presented in Appendix 8. The NPV of the project, taking into account the abandonment option, is $ 1.76 billion, and the value of the option to abandon is $183 million, or 5.55% of the project's gross value.

Option to expand the project. In case of the favorable market conditions, the company has the opportunity to increase the scale of the project in order to increase profits and benefit from economies of scale. The option to expand the scale of field development can be considered as an American call option. In this project, it was assumed that before the third year of implementation the company has the opportunity to increase the scale of the project by 20%. This may be due to the discovery of an error in the valuation of reserves or the introduction of a new technology that increases the oil recovery of the project, which will allow to produce oil as efficiently as possible. The increase by 20% is expected in view of the fact that only 70 thousand tons are developed from the reserves of 90 thousand tons of oil in the basic project and with the introduction of technology increasing the development efficiency, it is quite possible to increase production by 14 thousand tons per period. The present value of the project (V) is considered as the basic asset, and the exercise price is the present value of the additional investments that needed to be made for the expansion of the project (I_e). In this case, such investments will be additional investments in the development of drilling sites, field pipelines, which, as a result of the analysis of the project's cash flow, were estimated as $ 398 million. The option period is 3 years. This period is chosen due to the fact that, according to the project implementation plan, the feasibility study is being finalized at this stage, appraisal drilling have been completed and, since the fourth year, large-scale investments in infrastructure have begun. Thus, the temporary, legal and related financial costs for the expansion of the project will be minimized. As a risk-free rate, the yield to maturity of state

Eurobonds Russia-2020 equal to 2.49%[50] was accepted. Volatility of the project was 13.43%. Then, in accordance with formulas (17,18), the parameters k, μ, H, P were calculated:

Time step, k: $k = \sigma^2 \times T / N = 0{,}1343$

Drift μ: $\mu = r / \sigma^2 - 0{,}5 = -0{,}2398$

Coefficient, H: $H = \sqrt{k + (\mu k)^2} = 0{,}3679$

Probability, P : $P = 0{,}5 \left(1 + \mu k / H\right) = 0{,}4562$

In Table 3.3.3. the values of all option parameters are presented:

Table 3.3.3. Parameters of the option to expand the project.

Parameter	**Value**
Project value, V (mln $)	3 297
Exercise price, S (mln $)	398
Option period	3
Parameter	**Value**
Variance	13,43%
Risk-free rate	2,49%
Number of intervals	2
Time step, k	0,1343
Drift, m	-0,3146
Coefficient, H	0,3689
Probability, P	0,4427
Option value, (mln $)	328

Source: created by the author.

[50] Government bonds [Electronic source]// Rusbonds. Interfax Goup. – IA «Finam», [2004–2017]– Access mode: www.rusbonds.ru/cmngos.asp, free. – Screen title (20.04.2017).

Then, in accordance with the algorithm and the model proposed by L. Trigeorigs [90], a value tree was constructed, which was adjusted in accordance with the rule: $R' = R + max(0{,}2 \times V - I_e, 0)$ when the option occurred. The calculation is presented in Appendix 6. Thus, the NPV of the project, taking into account the option to expand, amounted to $ 1.91 billion, and the value of the option to expand the project was $328 million or 9.93% of the gross value of the project.

Option to decrease the scale. This option was considered for inclusion in the analysis, but due to the fact that oil production is rapidly declining at Russian fields and the production cost is low in Russia, it is unlikely that oil prices will fall to such a level that it would be necessary to reduce production. Especially, due to the fact that it is associated with high costs later on the production acceleration. Thus, option to decrease the scale was excluded from the valuation.

Further, on the basis of the three options described and evaluated above, various options' portfolios were constructed to find their value value, identify and analyze the interaction inside them.

Combinations of the options. In this paper, under the portfolio of options are considered several real options, embedded in the same project. Various combinations of options were evaluated: options to defer and expand, options to defer and abandon, options to expand and abandon and a portfolio of all three options. It should be noted that parameters of the options, such as the value of the underlying asset and the strike price, when combined in a portfolio, remained the same as in the valuation in isolation. The firk-free rate for the option with the longest duration was taken as the risk-free rate, so, for the portfolio of options to deferr and expand, it was 2.49%, and for the remaining 3.95%. In accordance with the algorithm given in Table 1.3.1, these options were sequentially incorporated into the project. The calculations are presented in appendices 7, 9, 10, 11. The results of the calculations are shown in Table 3.3.4.

Initially, the project was evaluated with a portfolio of options to defer and abandon. Its NPV was $3.42 billion, and the option premium was $1.84 billion, equivalent to 56% of the premium to the gross value of the project. Thus, the amount of the option premium for the portfolio of these options was 88 million lower than the premiums for these options separately, respectively.

Then the project was considered, which included options to defer and expand the project. NPV with embedded options amounted to $ 3.5 billion, the premium for such a portfolio of options was estimated at $1.95 billion, which is 59.02% of the premium to the gross value of the basic project. Options' interaction was negative and amounted to (-127) million dollars from the sum of real options values separately.

Table 3.3.4. Combinations of the options.

Type	NPV with option	Value of option premium	Interaction	% of gross project value
Value with one option				
Option to defer	3326	1746	-	52,94%
Option to abandon	1764	183	-	5,55%
Option to expand	1908	328	-	9,93%
Value with two options				
Options to defer and abandon	3421	1840	-88	55,81%
Options to defer and expand	3527	1946	-127	59,02%
Options to expand and abandon	2094	513	3	15,56%
Value with three options				
Options to defer, expand and abandon	3383	1803	-381	54,67%

Source: created by the author.

The portfolio was also evaluated with options to expand and abandon the project, and NPV with this portfolio amounted to $2.09 billion with an option premium of $513 million. It is worth mentioning that in this case there is a positive result from the interaction of two real options of $3 million.

The final combination of options considered in this paper was a combination of all three options. NPV of the project with this portfolio amounted to $3.38 billion, and the value of the option premium is $ 1.80 billion. The amount of the option premium for the portfolio of these options was 381 million lower, which is the result of negative synergies.

The interaction results discussion is presented in the table 3.3.5.

Based on the obtained results, it can be concluded that, indeed, while combining real options, the property of non-additivity of their premiums is observed. If the interacting options are opposite, in particular, call and put, the result of their interaction will most likely be characterized by a relatively low negative effect or even positive. In this paper, this is observed in the example of the interaction of a call option to defer and put option to abandon (the result of the interaction is (-88) million dollars), and a call option to expand and put an option to abandon (the result of the interaction is $3 million). In this situation, the use of call options is aimed at utilizing the benefits of favorable market situation, and the abandonment option helps to minimize losses from an undesirable market situation.

Table 3.3.5. Options' interaction discussion.

Type	Option premium	Interaction	Explanation
Combinations with two options			
Options to defer and abandon	1 840	-88	Relatively low negative synergy: 1) opposite options "call" and "put" 2) earlier exercise of deferral option (in 2 years), latter exercise of abandonment option (10 years) 3) both American options 4) significantly different level of being in the money
Options to defer and expand	1 946	-127	Relatively high negative synergy: 1) same type of options: "call" 2) earlier exercise of deferral option (in 2 years), latter exercise of expansion option (3years) 3) both American options 4) relatively different level of being in the money
Options to expand and abandon	513	3	Positive synergy: 1) opposite options "call" and "put" 2) earlier exercise of expansion option (in 3 years), latter exercise of abandonment option (10 years) 3) both American options 4) significantly different level of being in the money
Combination with three options			
Options to defer, expand and abandon	1 803	-381	High negative synergy: 1) opposite options "call" and "put" 2) earlier exercise of deferral option (in 2 years), then expansion option (in 2 years), latter exercise of abandonment option (10 years) 3) American options 4) significantly different level of being in the money

Source: created by the author.

In the example of a portfolio of two call options to defer and abandon, there is a significant negative synergy (-127 million dollars), compared to other combinations, and as a result of their interaction, the option premium becomes 5% lower than the sum of individual premiums.

So, it can be concluded that it is worth combining real options which maximize profits as a result of positive market movements and minimize losses from an unfavorable market situation.

This is also reasonable, if we consider real options as a tool of risk management, because then the inclusion of options in the portfolio can improve the implementation of the project in both undesirable and favorable market conditions and influence positively project's characteristics of risk exposure.

It is also worth mentioning that the magnitude of the synergistic effect from the combination of options largely depends on how much the option is “in the money” and “out of the money”, and also on the sequence and time, when real options are incorporated into the project. So, in this example, the first option in the project is an option to abandon, since its time period is 10 years, but when building a model with adding an option to expand in period 3 and an option to defer in period 2, its value is significantly declined as a result of it. The degree of impact on the option premium for subsequent options is also reduced.

Thus, the relatively low absolute negative synergy for a portfolio of options to defer and abandon is due to the fact that they are opposite, and option to defer has a high premium value in money, unlike the option to abandon. The positive value of the synergy for options to expand and abandon is due to their different directions of action, as well as the relative proportionality of their option premiums.

Relatively high negative synergy is observed in the portfolio of options to defer and expand because they are both call options with a fairly high option premium and almost the same maturity.

If you determine the criterion for choosing a portfolio from all combinations of real options, then the suitable one is the portfolio that contains the maximum number of options. While accounting for all real options incorporated into the project, the more accurate estimate of the project value can be obtained. Also, the incorporation of the maximum number of options in the portfolio is reasonable from the viewpoint of risk management, because in this way management has the most flexible tool for adapting to the changing conditions of the external environment.

Conclusions

This chapter analyzed trends in the oil and gas market, such as increased demand for liquid hydrocarbons due to population growth; urbanization; motorization in developing countries; growth of oil production in North America; stagnation in the European hydrocarbon market; decline in production in Russia; need to search for new gas markets for Russia.

The model project was also created for the exploration and operation of a conventional oil and gas field. The basic NPV accounted for 1.58 billion dollars. Then, basing on the analysis and evaluation performed, the real options were identified and incorporated in the project, namely the options to defer, abandon and expand. Thus, the net present value of the project with an option to defer was $ 3.33 billion, or 53% premium to the gross value of the project. NPV with an option to expand amounted to $ 1.91 billion, or 10% premium to the gross value of the project. The net present value of the project with the option to abandon was $ 1.76 billion, and the premium to the gross project value was 5.55%. Accordingly, the existence of the options in the project significantly increases its value for the company, which should be taken into account in such large-scale projects as the projects of oil and gas fields exploration.

Further, the project was evaluated, taking into account various combinations of real options. The net present value of the project with a portfolio of options to defer and abandon was estimated at $3.42 billion, while the option premium was $ 1.84 billion. The NPV of the project, including options to defer and expand, amounted to $ 3.53 billion, and the premium for such an options' portfolio was estimated as$ 1.95 billion, or 59% of the premium to the gross project value. The result of real options interaction in the example of these two portfolios turned out to be negative, but different in scale ((-88) million and (-127) million dollars). The project was also evaluated with the options to expand and abandon, and the option premium was $513 million. In this case, there was a positive synergy of $3 million from the interaction of two real options. In conclusion, a combination of all three options was considered, the NPV of the project accounted for 3.38 billion dollars, and the value of the option premium was equal to 1.80 billion dollars. However, there was a negative effect from synergy again.

Thus, it was concluded that real options in the portfolio demonstrate the property of non-additivity of option premiums to the project. Moreover, combining opposite call and put options allows to minimize the negative interaction effect or even leads to the positive synergy. It was also concluded that the level of real options interaction in this project also depends on how much the option is "in the money" and "out of the money" and the sequence of their integration. As a criterion for choosing the most suitable portfolio in the evaluation, it was suggested to consider the portfolio, which contains the maximum number of options, as this would allow to obtain the most accurate estimate of the project, and also gives management the proper tool to respond to changes in the external environment.

CONCLUSION

Throughout the analysis of the literature, it was concluded that there is a research gap, considering investigation of real options' interactions for oil and gas projects. Analysis of the main methods of real options' estimation made it possible to conclude that the logarithmic binomial model would be the most appropriate methodology within the frame of this paper, since it allows to evaluate the combinations of real options as a portfolio and analyze their interactions.

Also, throughout the analysis of the oil and gas project's phases, the preparatory stage, the stage of construction and development, and the stage of direct operation were identified as typical phases. Risk analysis of oil and gas industry projects showed that the volatility of oil prices and the risk of unconfirmed reserves are the main sources of uncertainty in the projects. Consequently, it was concluded that the main real options for such projects are options to delay, abandon and change the scale.

Market analysis has revealed trends such as increased demand for the liquid hydrocarbons due to growing population; urbanization; motorization in developing countries; growth of gas consumption at a faster rate than oil; stagnation in the European hydrocarbon market; decline in production in Russia.

As a result of a financial model creation for the oil & gas field development and operation project, the basic NPV project of 1.58 billion dollars is obtained. There are also identified three main real options presented in the project, namely option to defer, option to abandon, option to expand.

While evaluating the real options individually, the following results are obtained: the net present value of the project with the option to defer is $3.33 billion, or 53% option premium to the gross value of the project; NPV with an option to expand amounted to $1.91 billion, or 9.93% option premium to the gross project value; net present value of the project with the option to abandon is $ 1.76 billion, and the option premium to the project's gross value is 5.55%. Basing on the results obtained, it can be concluded that the methodology of real options allows to expand the set of tools in the evaluation of investments, taking into account the uncertainty in the decision-making process and avoiding underestimation of the project, while applying traditional methods.

The evaluation of the project, taking into account various portfolios of real options, gave the following results. The net present value of the project with a portfolio of options to defer and abandon is estimated at $3.42 billion, and the option premium is 56% of the project's gross value, resulting in negative synergies of (-88) million dollars. NPV of the project, including options to defer and expand amounted to $3.53 billion, and the premium for such a portfolio of options is estimated at 59.02% of the basic gross project value, and the result of the interaction is negative synergy of (-127) million dollars. The portfolio is also evaluated with options to expand and abandon the project, in this case the option premium is 15.56% of the project's gross value, and also positive synergy of $3 million is observed. In addition, a combination of all three options is considered, in which the NPV of the project is amounted to $ 3.38 billion, and the option premium is 54.7% of the project's gross value, resulting in negative synergies of $(-381) million.

As a result, the statement of the non-additivity of the option premiums to the project is confirmed. It is also shown that if the options are opposite, the result of their interaction will be most likely characterized by a relatively low negative effect or, in rare cases, positive. Thus, it was concluded that it is necessary to include multidirectional real options in projects, if there is such an opportunity. This strategy is applicable also due to the fact that, if we consider real options as a method of risk management, then the inclusion of options in the portfolio, which react differently to changes in the market, should improve the project's risk exposure indicators. It is also noted that the synergistic effect from the combination of the options largely depends on how much the option is "in or out of the money", sequence and time, when real options are incorporated into the project. As a criterion for choosing the best portfolio of real options, it is suggested to consider as the best, the one that includes the maximum number of options. The reason is that there is a more correct project value, taking into account all real options incorporated in the project, and management can apply the diverse tool for adaptation to the external environment.

It should be noted that the results of this study, in particular, the values of option premiums and interactions received, should be applied carefully to other projects in the industry, since the premium value is highly sensitive to project input parameters, such as project cash flow, volatility, risk-free rate. Also, real options approach in the evaluation of projects takes into account its specific risks, which are rather subjective characteristic.

As further directions of the research on this topic, the same study on real-life oil and gas project can be conducted. It is also possible to include other types of options, such as an option to develop a new deposit, option to stop the project temporary. Moreover, one of the research directions could be creating a similar research on the projects in other sectors, such as pharmaceuticals, information technologies industries.

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APPENDICES

Appendix 1. Revenue structure, USD.

t	Oil production (bbl per year)	Oil price,$ per bbl	Oil reveneue ,$	Gas production, th m3	Gas price, $ per th m3	Gas revenue ,$	Total revenue ,$
1	-	-	-	-	-	-	-
2	-	-	-	-	-	-	-
3	-	-	-	-	-	-	-
4	-	-	-	-	-	-	-
5	6 502 890	78	508 181 625	350 000	157	55 024 405	563 206 030
6	19 508 671	81	1 574 583 035	1 050 000	152	159 969 959	1 734 552 993
7	32 514 451	82	2 675 281 051	1 750 000	153	268 202 395	2 943 483 446
8	39 017 341	84	3 266 421 412	2 100 000	158	331 805 727	3 598 227 139
9	58 526 012	86	5 046 829 017	3 150 000	161	508 100 008	5 554 929 024
10	65 028 902	89	5 758 542 637	3 500 000	166	581 564 413	6 340 107 050
11	65 028 902	90	5 852 412 637	3 500 000	170	595 476 848	6 447 889 485
12	58 526 012	91	5 306 952 089	3 150 000	174	548 436 484	5 855 388 573
13	52 023 121	92	4 789 850 150	2 800 000	178	497 393 787	5 287 243 937
14	39 017 341	95	3 688 094 575	2 100 000	179	376 241 468	4 064 336 043
15	32 514 451	97	3 147 870 759	1 750 000	183	319 854 375	3 467 725 134
16	26 011 561	100	2 588 873 254	1 400 000	183	255 938 231	2 844 811 485
17	26 011 561	100	2 592 031 812	1 400 000	180	252 067 012	2 844 098 825
18	19 508 671	101	1 979 246 842	1 050 000	179	188 104 307	2 167 351 149
19	19 508 671	102	1 992 817 424	1 050 000	182	191 368 886	2 184 186 310
20	13 005 780	105	1 365 533 909	700 000	182	127 089 159	1 492 623 068
21	13 005 780	106	1 372 340 627	700 000	182	127 097 153	1 499 437 780
22	13 005 780	107	1 387 351 873	700 000	181	126 661 134	1 514 013 007
23	6 502 890	108	704 821 819	350 000	182	63 672 248	768 494 066
24	6 502 890	109	711 189 761	350 000	181	63 486 265	774 676 026
25	6 502 890	110	715 586 423	350 000	182	63 729 898	779 316 321
26	6 502 890	110	716 873 339	350 000	185	64 895 652	781 768 991

t	Oil production (bbl per year)	Oil price,$ per bbl	Oil reveneue ,$	Gas production, th m3	Gas price, $ per th m3	Gas revenue ,$	Total revenue ,$
27	6 502 890	111	720 763 504	350 000	190	66 527 358	787 290 863
28	6 502 890	111	724 287 128	350 000	192	67 159 547	791 446 675
29	6 502 890	112	728 405 662	350 000	194	68 047 097	796 452 759
30	6 502 890	113	734 607 104	350 000	197	68 830 247	803 437 351

Appendix 2. Export tariff, taxes, operating costs, USD.

t	Export tax	Taxes, other than profit tax	Production drilling	General OPEX
1	-	-	-	-
2	-	-	-	-
3	-	-	-	2 093 039
4	-	-	-	57 254 167
5	168 961 809	95 745 025	111 896 636	349 865 144
6	520 365 898	294 874 009	202 161 160	555 870 219
7	883 045 034	500 392 186	187 567 518	635 825 205
8	1 079 468 142	611 698 614	174 565 004	668 994 084
9	1 666 478 707	944 337 934	199 559 094	831 960 718
10	1 902 032 115	1 077 818 199	173 182 900	852 295 462
11	1 934 366 845	1 096 141 212	188 260 034	868 046 554
12	1 756 616 572	995 416 057	127 616 473	762 273 462
13	1 586 173 181	898 831 469	111 442 447	700 752 849
14	1 219 300 813	690 937 127	111 521 564	609 929 398
15	1 040 317 540	589 513 273	111 598 727	564 632 843
16	853 443 446	483 617 953	112 217 011	519 406 347
17	853 229 647	483 496 800	-	405 300 003
18	650 205 345	368 449 695	-	359 779 771
19	655 255 893	371 311 673	-	359 779 771
20	447 786 920	253 745 922	-	314 259 540
21	449 831 334	254 904 423	-	314 259 540
22	454 203 902	257 382 211	-	314 259 540
23	230 548 220	130 643 991	-	268 739 309
24	232 402 808	131 694 924	-	268 739 309
25	233 794 896	132 483 775	-	268 739 309
26	234 530 697	132 900 728	-	268 739 309
27	236 187 259	133 839 447	-	268 739 309

t	Export tax	Taxes, other than profit tax	Production drilling	General OPEX
28	237 434 002	134 545 935	-	268 739 309
29	238 935 828	135 396 969	-	268 739 309
30	241 031 205	136 584 350	-	268 739 309
31	-	-	-	322 718 650

Appendix 3. CAPEX, USD.

t	Estimation drilling	Infrastructure	Central oil preparation platform	Wells	Internal oil pipelines	External oil pipelines	External gas pipeline	Teminal	Total CAPEX
1	19 535 027								19 535 027
2	19 535 027								19 535 027
3						41 804 958	4 297 706	12 502 417	58 605 082
4		26 762 987	379 760 930	3 320 955	3 907 005	721 428 557	226 606 316	127 563 728	1 489 350 478
5		4 688 407	205 117 786	47 470 116	11 721 016	571 985 598	139 284 744	111 740 356	1 092 008 024
6		7 814 011	113 889 209	27 935 089	17 776 875	330 337 311	65 246 991	54 502 726	617 502 212
7		5 665 158	45 516 614	21 293 180	11 721 016				84 195 967
8		9 962 864	15 237 321	31 060 693	17 776 875				74 037 753
9		7 814 011		23 246 682	17 776 875				48 837 568
10		5 665 158		19 339 677	11 721 016				36 725 851
11		5 665 158		7 814 011	5 860 508				19 339 677
12		2 148 853		5 274 457					7 423 310
13				3 125 604					3 125 604
14				2 344 203					2 344 203
15				2 344 203					2 344 203
16				2 344 203					2 344 203
17				2 148 853					2 148 853

Appendix 4. NPV, USD.

t	Total revenue	Total operating expenses	EBIT	Profit tax (20%)	EBIT (1-t)	Amortization	CAPEX	Change in WC	FCF	Disc. coeff.	DFCF
1		-	-	-	-	-	19 535 027	-	-19 535 027	1,16	-16 776 518
2		-	-	-	-	-	19 535 027	-	-19 535 027	1,36	-14 407 534
3		2 093 039	-2 093 039	-	-2 093 039	2 093 039	58 605 082	-	-58 605 082	1,58	-37 119 210
4		57 254 167	-57 254 167	-	-57 254 167	57 254 167	1 489 350 478	-	-1 489 350 478	1,84	-810 117 806
5	563 206 030	349 865 144	-51 365 949	-	-51 365 949	99 254 476	1 092 008 024	22 021 356	-1 066 140 852	2,14	-498 027 897
6	1 734 552 993	555 870 219	363 442 867	72 688 573	290 754 294	123 954 565	617 502 212	45 799 666	-248 593 019	2,49	-99 727 707
7	2 943 483 446	635 825 205	924 221 022	184 844 204	739 376 817	127 462 730	84 195 967	47 269 181	735 374 399	2,90	253 351 352
8	3 598 227 139	668 994 084	1 238 066 300	247 613 260	990 453 040	128 113 892	74 037 753	25 600 478	1 018 928 700	3,38	301 471 549
9	5 554 929 024	831 960 718	2 112 151 665	422 430 333	1 689 721 332	129 525 742	48 837 568	76 507 044	1 693 902 462	3,94	430 406 433
10	6 340 107 050	852 295 462	2 507 961 275	501 592 255	2 006 369 020	130 716 448	36 725 851	30 700 461	2 069 659 156	4,58	451 623 987
11	6 447 889 485	868 046 554	2 549 334 873	509 866 975	2 039 467 898	131 390 407	19 339 677	4 214 293	2 147 304 335	5,34	402 401 499
12	5 855 388 573	762 273 462	2 341 082 482	468 216 496	1 872 865 985	131 781 107	7 423 310	-23 166 786	2 020 390 568	6,21	325 154 028
13	5 287 243 937	700 752 849	2 101 486 437	420 297 287	1 681 189 150	131 954 752	3 125 604	-22 214 455	1 832 232 753	7,24	253 234 146
14	4 064 336 043	609 929 398	1 544 168 705	308 833 741	1 235 334 964	132 092 646	2 344 203	-47 815 699	1 412 899 105	8,43	167 702 907
15	3 467 725 134	564 632 843	1 273 261 478	254 652 296	1 018 609 182	132 239 159	2 344 203	-23 327 487	1 171 831 624	9,81	119 448 987
16	2 844 811 485	519 406 347	988 343 740	197 668 748	790 674 992	131 914 611	2 344 203	-24 355 924	944 601 323	11,42	82 690 120
17	2 844 098 825	405 300 003	1 102 072 374	220 414 475	881 657 899	130 025 277	2 148 853	-27 865	1 009 562 188	13,30	75 897 237
18	2 167 351 149	359 779 771	788 916 337	157 783 267	631 133 070	130 025 277	-	-26 460 834	787 619 181	15,49	50 850 707
19	2 184 186 310	359 779 771	797 838 973	159 567 795	638 271 178	130 025 277	-	658 255	767 638 200	18,04	42 562 302
20	1 492 623 068	314 259 540	476 830 686	95 366 137	381 464 549	130 025 277	-	-27 040 123	538 529 948	21,00	25 642 845
21	1 499 437 780	314 259 540	480 442 483	96 088 497	384 353 987	130 025 277	-	266 455	514 112 808	24,45	21 023 382
22	1 514 013 007	314 259 540	488 167 353	97 633 471	390 533 883	130 025 277	-	569 891	519 989 268	28,48	18 261 076

t	Total revenue	Total operating expenses	EBIT	Profit tax (20%)	EBIT (1-t)	Amortization	CAPEX	Change in WC	FCF	Disc. coeff.	DFCF
23	768 494 066	268 739 309	138 562 546	27 712 509	110 850 037	130 025 277	-	-29 149 791	270 025 104	33,16	8 143 741
24	774 676 026	268 739 309	141 838 985	28 367 797	113 471 188	130 025 277	-	241 715	243 254 750	38,61	6 300 412
25	779 316 321	268 739 309	144 298 341	28 859 668	115 438 673	130 025 277	-	181 436	245 282 514	44,96	5 455 845
26	781 768 991	268 739 309	145 598 256	29 119 651	116 478 605	130 025 277	-	95 899	246 407 982	52,35	4 706 933
27	787 290 863	268 739 309	148 524 848	29 704 970	118 819 879	130 025 277	-	215 905	248 629 250	60,96	4 078 714
28	791 446 675	268 739 309	150 727 429	30 145 486	120 581 943	130 025 277	-	162 492	250 444 727	70,98	3 528 343
29	796 452 759	268 739 309	153 380 653	30 676 131	122 704 523	130 025 277	-	195 738	252 534 061	82,65	3 055 390
30	803 437 351	268 739 309	157 082 487	31 416 497	125 665 990	130 025 277	-	273 098	255 418 169	96,24	2 653 911
31		322 718 650	-322 718 650	-	-322 718 650	-	-		-322 718 650	112,07	-2 879 694
NPV		1 580 589 478									
IRR		30%									

Appendix 5. Option to defer, mln USD.

t	0	1	2
			6876
			12039
		4762	5163
		7873	3297
Project without option	3297	3112	4881
Project with option	5043	2283	1583
Option to defer	1746	2986	1581
		703	1581

Appendix 6. Option to expand, mln USD.

t	0	1	2	3
				9 931
				11 519
			6 876	1 588
			7 867	4 762
		4 762	991	5 316
		5 343	3 297	554
Project without option	3 297	582	3 573	2 283
Project with option	3 625	2 283	276	2 342
Option to expand	328	2 418	1 581	59
		135	1 607	1 095
			26	1 095
				-

Appendix 7. Combination of option to defer and expand, mln USD.

t	0	1	2	3
				9 931
				11 519
			6 876	1 588
		4 762	12 725	4 762
Project without option	3 297	8 249	5 849	5 316
Project with portfolio	5 243	3 488	3 297	554
Option to defer and expand	1 946	2 283	5 018	2 283
		3 047	1 721	2 342
		764	1 581	59
			1 581	1 095
			-	1 095
				-

Appendix 8. Option to abandon, mln USD.

	0	1	2	3	4	5	6	7	8	9	10
											130 093
											130 093
										90 083	-
									62 378	90 083	62 378
								43 194	62 378	-	62 378
							29 910	43 194	-	43 194	-
						20 711	29 910	-	29 910	43 194	29 910
						20 711	-	20 711	29 910	-	29 910
					14 341	-	14 341	20 711	-	20 711	-
				9 931	14 341	9 931	14 341	-	14 341	20 711	14 341
			6 876	9 939	-	9 931	-	9 931	14 341	-	14 341
		4 762	6 918	9	6 876	-	6 876	9 931	-	9 931	-
Project without option	3 297	4 863	41	4 762	6 898	4 762	6 881	-	6 876	9 931	6 876
Project with option	3 480	101	3 297	4 838	22	4 807	4	4 762	6 876	-	6 876
Option to abandon	183	2 283	3 460	76	3 297	45	3 297	4 773	-	4 762	-
		2 552	163	2 283	3 429	2 283	3 384	11	3 297	4 762	3 297
		269	1 581	2 534	132	2 501	86	2 283	3 322	-	3 297
			1 962	251	1 581	218	1 581	2 442	24	2 283	-
			381	1 095	1 954	1 095	1 929	159	1 581	2 332	1 581
				1 618	373	1 630	348	1 095	1 869	49	1 676
				523	758	535	758	1 631	288	1 095	95
					1 450	525	1 495	537	758	1 611	758
					692	1 404	737	525	1 549	517	1 676
						879	363	1 489	791	525	918
							1 431	964	363	1 611	363
							1 068	252	1 549	1 087	1 676
								1 489	1 186	252	1 313
								1 237	174	1 611	174
									1 549	1 360	1 676
									1 375	121	1 502
										1 611	84
										1 491	1 676
											1 593

Appendix 9. Combination of the options to defer and abandon, mln USD.

t	0	1	2	3	4	5	6	7	8	9	10
		defer									abandon
											130 093
											130 093
										90 083	-
									62 378	90 083	62 378
								43 194	62 378	-	62 378
						6	29 910	43 194	-	43 194	-
						20 711	29 910	-	29 910	43 194	29 910
						20 711	-	20 711	29 910	-	29 910
					14 341	-	14 341	20 711	-	20 711	-
				9 931	14 341	9 931	14 341	-	14 341	20 711	14 341
			6 876	9 939	-	9 931	-	9 931	14 341	-	14 341
		4 762	12 039	9	6 876	-	6 876	9 931	-	9 931	-
Project without option	3 297	7 888	5 163	4 762	6 898	4 762	6 881	-	6 876	9 931	6 876
Project with portfolio	5 138	3 127	3 297	4 838	22	4 807	4	4 762	6 876	-	6 876
Option to defer and abandon	1 840	2 283	4 909	76	3 297	45	3 297	4 773	-	4 762	-
		3 157	1 612	2 283	3 429	2 283	3 384	11	3 297	4 762	3 297
		874	1 581	2 534	132	2 501	86	2 283	3 322	-	3 297
			1 886	251	1 581	218	1 581	2 442	24	2 283	-
			305	1 095	1 954	1 095	1 929	159	1 581	2 332	1 581
				1 618	373	1 630	348	1 095	1 869	49	1 676
				523	758	535	758	1 631	288	1 095	95
					1 450	525	1 495	537	758	1 611	758
					692	1 404	737	525	1 549	517	1 676
						879	363	1 489	791	525	918
							1 431	964	363	1 611	363
							1 068	252	1 549	1 087	1 676
								1 489	1 186	252	1 313
								1 237	174	1 611	174
									1 549	1 360	1 676
									1 375	121	1 502
										1 611	84
										1 491	1 676
											1 593

Appendix 10. Combination of options to abandon and expand, mln USD.

t	0	1	2	3	4	5	6	7	8	9	10
			expand								abandon
											130 093
											130 093
										90 083	-
									62 378	90 083	62 378
								43 194	62 378	-	62 378
							29 910	43 194	-	43 194	-
						20 711	29 910	-	29 910	43 194	29 910
						20 711	-	20 711	29 910	-	29 910
					14 341	-	14 341	20 711	-	20 711	-
				9 931	14 341	9 931	14 341	-	14 341	20 711	14 341
			6 876	11 527	-	9 931	-	9 931	14 341	-	14 341
		4 762	7 910	1 597	6 876	-	6 876	9 931	-	9 931	-
Project without option	3 297	5 447	1 034	4 762	6 898	4 762	6 881	-	6 876	9 931	6 876
Project with portfolio	3 810	685	3 297	5 392	22	4 807	4	4 762	6 876	-	6 876
Option to expad and abandon	513	2 283	3 736	631	3 297	45	3 297	4 773	-	4 762	-
		2 688	439	2 283	3 429	2 283	3 384	11	3 297	4 762	3 297
		405	1 581	2 592	132	2 501	86	2 283	3 322	-	3 297
			1 988	309	1 581	218	1 581	2 442	24	2 283	-
			407	1 095	1 954	1 095	1 929	159	1 581	2 332	1 581
				1 618	373	1 630	348	1 095	1 869	49	1 676
				523	758	535	758	1 631	288	1 095	95
					1 450	525	1 495	537	758	1 611	758
					692	1 404	737	525	1 549	517	1 676
						879	363	1 489	791	525	918
							1 431	964	363	1 611	363
							1 068	252	1 549	1 087	1 676
								1 489	1 186	252	1 313
								1 237	174	1 611	174
									1 549	1 360	1 676
									1 375	121	1 502
										1 611	84
										1 491	1 676
											1 593

Appendix 11. Combination of options to defer, expand, abandon, mln USD.

	0	1	2	3	4	5	6	7	8	9	10
			defer	expand							abandon
											130 093
											130 093
										90 083	-
									62 378	90 083	62 378
								43 194	62 378	-	62 378
						-	29 910	43 194	-	43 194	-
						20 711	29 910	-	29 910	43 194	29 910
						20 711	-	20 711	29 910	-	29 910
					14 341	-	14 341	20 711	-	20 711	-
				9 931	14 341	9 931	14 341	-	14 341	20 711	14 341
			6 876	11 527	-	9 931	-	9 931	14 341	-	14 341
		4 762	10 134	1 597	6 876	-	6 876	9 931	-	9 931	-
Project without option	3 297	7 485	3 257	4 762	6 898	4 762	6 881	-	6 876	9 931	6 876
Project with portfolio	5 100	2 723	3 297	10 485	22	4 807	4	4 762	6 876	-	6 876
Options to defer, expand, abandon	1 803	2 283	5 768	5 723	3 297	45	3 297	4 773	-	4 762	-
		3 551	2 470	2 283	3 429	2 283	3 384	11	3 297	4 762	3 297
		1 268	1 581	2 592	132	2 501	86	2 283	3 322	-	3 297
			1 911	309	1 581	218	1 581	2 442	24	2 283	-
			330	1 095	1 954	1 095	1 929	159	1 581	2 332	1 581
				1 618	373	1 630	348	1 095	1 869	49	1 676
				523	758	535	758	1 631	288	1 095	95
					1 450	525	1 495	537	758	1 611	758
					692	1 404	737	525	1 549	517	1 676
						879	363	1 489	791	525	918
							1 431	964	363	1 611	363
							1 068	252	1 549	1 087	1 676
								1 489	1 186	252	1 313
								1 237	174	1 611	174
									1 549	1 360	1 676
									1 375	121	1 502
										1 611	84
										1 491	1 676
											1 593