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AN ESTIMATION OF PROFITABILITY OF INVESTMENT PROJECTS IN THE OIL AND GAS INDUSTRY USING REAL OPTIONS THEORY

OCENA OPŁACALNOŚCI PROJEKTÓW INWESTYCYJNYCH W PRZEMYŚLE NAFTOWYM Z WYKORZYSTANIEM TEORII OPCJI REALNYCH

Paper discusses issues relating to the valuation of investment efficiency in the oil and gas industry using a real options theory. The example of investment pricing using real options was depicted and it was confronted with the analysis executed with the use of traditional methods.

Indicators commonly used to evaluate profitability of investment projects, based on a discounted cash flow method, have a few significant drawbacks, the most meaningful of which is staticity which means that any changes resulting from a decision process during the time of investment cannot be taken into consideration. In accordance with a methodology that is currently used, investment projects are analysed in a way that all the key decisions are made at the beginning and are irreversible. This approach assumes, that all the cash flows are specified and does not let the fact that during the time of investment there may appear new information, which could change its original form. What is also not analysed is the possibility of readjustment, due to staff managment's decisions, to the current market conditions, by expanding, speeding up/slowing down, abandoning or changing an outline of the undertaking. In result, traditional methods of investment projects valuation may lead to taking wrong decisions, e.g. giving up an owned exploitation licence or untimely liquidation of boreholes, which seem to be unprofitable.

Due to all the above-mentioned there appears the necessity of finding some other methods which would let one make real and adequate estimations about investments in a petroleum industry especially when it comes to unconventional resources extraction. One of the methods which has been recently getting more and more approval in a world petroleum economics, is a real options pricing method. A real option is a right (but not an obligation) to make a decision connected with an investment in a specified time or time interval. According to the method a static model of pricing using DCF is no longer used; an investment project is divided into a series of steps and after each one there is a range of possible investment decisions, technical and organizational issues and all the others called 'real options'. This lets one take many different varieties of modyfiying a strategy while pricing the project. This also makes it possible to react to the changing inner and outer situation and introducing new information while accomplishing the investment project. Owing to those, the decision process is a continuous operation, what is an actual vision of a real investment project management in the petroleum industry.

Keywords: real options, profitability analysis, oil and gas industry

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W artykule omówiono kwestie związane z wykorzystaniem do oceny efektywności inwestycji w przemyśle naftowym teorii opcji realnych. Przedstawiono przykład wyceny inwestycji za pomocą opcji realnych i skonfrontowano go z analizą przeprowadzoną z wykorzystaniem tradycyjnych metod.

Używane powszechnie do oceny opłacalności projektów inwestycyjnych wskaźniki, oparte na metodzie zdyskontowanych przepływów pieniężnych, posiadają istotne wady, z których jedną z najważniejszych jest statyczność, czyli brak możliwości uwzględnienia zmian wynikających z procesu decyzyjnego w trakcie trwania inwestycji. Zgodnie z obowiązującą aktualnie metodyką analizuje się projekty inwestycyjne w ten sposób, że kluczowe decyzje zapadają na początku i są nieodwracalne. Podejście to zakłada, że przepływy pieniężne są ustalone i nie uwzględnia faktu, iż w czasie trwania inwestycji mogą pojawić się nowe informacje, które zmienią jej oryginalny kształt. Nie analizuje się również możliwości dostosowania przez decyzje kadry zarządzającej do aktualnych warunków rynkowych poprzez np.: rozszerzenie, przyspieszenie/zwolnienie, porzucenie czy zmianę profilu przedsięwzięcia. W rezultacie tradycyjne metody oceny projektów inwestycyjnych mogą doprowadzić do podjęcia błędnych decyzji. np. o rezygnacji z posiadanej koncesji eksploatacyjnej czy przedwczesnej likwidacji odwiertów, które wydają się nierentowne.

W związku z powyższym istnieje konieczność zastosowania innych metod, pozwalających na urealnienie sposobu dokonywania wyceny wartości złóż oraz inwestycji w przemyśle naftowym, zwłaszcza w przypadku eksploatacji zasobów niekonwencjonalnych. Jedną z nich, zyskującą w ostatnich latach coraz większe uznanie w światowej ekonomice naftowej, jest metoda wyceny opcji realnych. Opcja realna jest prawem, (ale nie obowiązkiem) do podjęcia decyzji związanej z inwestycją w określonym czasie lub przedziale czasu. Odrzuca się więc statyczny model wyceny metodą DCF i dzieli projekt inwestycyjny na szereg kroków, po których istnieje zestaw możliwych do podjęcia decyzji inwestycyjnych, technicznych, organizacyjnych lub innych, zwanych „opcjami realnymi". Pozwala to na uwzględnienie w wycenie elastyczności w zakresie modyfikowania strategii, reagowania na zmieniającą się sytuację wewnętrzną i zewnętrzną oraz pojawienie się w trakcie realizacji inwestycji nowych informacji. Dzięki temu proces decyzyjny ma charakter ciągły, co odpowiada sytuacji rzeczywistego zarządzania projektem inwestycyjnym w przemyśle naftowym.

Słowa kluczowe: opcje realne, analiza efektywności ekonomicznej, przemysł naftowy

1. Introduction

Indicators commonly used to valuate profitability of investment projects based on a discounted cash flow method, have a few significant drawbacks, the most meaningful of which is staticity, which means that any changes resulting from a decision process during the time of investment cannot be introduced. Investment projects are analysed in a way that all the key decisions are made at the beginning and are irreversible, and all the cash flows are determined and do not let the fact, that during the investment period some new information may occur and change its original form. Another thing, which can come out due to staff managment's decisions, and the analyse of which is also neglected, is a possibility of adapting the project to current market conditions which includes expanding, speeding up/ slowing down, abandoning or changing an outline of an undertaking. Additionally, cash flow discounting favours short-term projects. That means all the projects assuming fast and intensive reservoir exploitation are assessed to be more profitable, which unfortunately is not always true, because in some cases the best solution is to wait for more advantageous market conditions or until some new technologies are released. In result, traditional methods of investment projects valuation may lead to wrong decisions, e.g. giving up an owned exploitation licence or untimely liquidation of wells, which seem to be unprofitable.

Due to all the above-mentioned there appears the necessity of finding some other methods which would allow making real and adequate estimations about investments in the oil and gas industry, especially when it comes to unconventional deposits extraction. Unconventional resources are characteristic of a unique kind of risk – the geological risk is usually smaller and the economic one is usually bigger than in case of conventional resources (Gray et al., 2007). That necessity is also becoming more significant in the light of inevitable liberalization of European gas market (Frączek et al., 2009).

The answer to the need of use of some better methods enabling evaluation of investments' effectivness is the real options pricing method, which has recently been getting more and more approval in a world oil and gas industry. A real option is a right (but not an obligation) to make a decision connected with an investment in a defined time or time interval. According to the method a static model of pricing using discounted cash flow is no longer used. An investment project is divided into a series of steps, and after each one there is a range of possible investment, technical and organizational decisions called 'real options'. This flexible model allows taking into consideration many different varieties of modifying a strategy while pricing the project. Moreover it is possible to react to the changing inner and outer situation and introduce new information while realizing the investment project. Owing to those, the decision process is a continuous operation, what is an actual imaging of a real investment project management in the oil and gas industry.

2. Financial options

Real options come from financial options. Financial options are derivatives, which work on the basis of a contract, i.e. contrary to obligations or shares, financial options do not come into being by an emission but after conclusion of a transaction between a buyer (purchaser) and a seller (writer). Underlying instruments, in most cases, are shares, stock market indices and foreign currencies. All of the mentioned give their holder the law, but not the obligation, to buy or sell an asset at a set price. What is significant, is the fact, that the holder of the option does not have to use the described possibility. But if the holder decides to use his right, the writer of the option is obliged to sell or buy a certain security at a certain price set earlier. A settlement of the option transaction is most often in cash rather than by delivering the underlying asset (Hull, 1997).

Two basic types of options are distinguished:

a) a call option, which authorizes its holder to buy a specified asset at a specified price on or before the expiration date of the contract.
b) a put option, which gives its holder the right to sell a specified asset at a specified price on or before the expiration date of the contract.

The specified price for which an asset may be purchased or sold is called either strike price or exercise price, and the date on or before which the option can be exercised is called the expiry date.

On account of exercise of options we divide them into European and American. A European option may be exercised only on the day of expiry, whereas an American option may be exercised at any time before the expiry date (Hull, 1997).

3. Real options

In case of real options underlying assets on which such options are written are cash flows, which will be generated by the investment, as well as the value of all the following options resulting from accomplishment of the investment.

Strategic investment decisions, which are made in every company, in fact relate to purchase, exercise, abandonment or allowing the real options to expire. Management's decisions create call and put options, which give them the law, but not the obligation, to take advantage of all the opportunities included in these options in order to increase the value of the enterprise. The main advantage of using the real option theory is a combination of flexibility in managing as well as investment pricing process. An example of a real option in the oil and gas industry can be holding a prospection licence, which gives one a right to carry out prospection research, at the same time letting him do that at his discretion. Such an option can be either exercised or the enterprise management can let it expire. After research and locating a carbohydrates deposit a number of another options may appear and the most obvious of them will be an option of developing the deposit and start of production. Basing on earlier researches' results, the company may start production or just give it up. It may as well postpone the start of production moment which is also an example of a real option.

One of the key differences between classic indicators of economical profitability estimation based on discounted cash flows and the real options is a fact, that in case of the first ones the predominant criterion of profitability is an excess of a present (discounted) value of takings compared to the current value of outflows generated by an investment. In this method it is the time that plays a crucial role, and every retardation in a decision process is followed by some negative consequences. In the case of real options waiting and postponing making a decision may have a positive effect both on the investment and all the enterprise (Brach, 2003).

Fundamental types of real options are distinguished:

Deferment option

This option allows postponing decision concerning investment until new useful information emerge or until market surroundings get better. Owing to this option an investor does not have to make an irrevocable decision but can wait for beneficial changes or any additional information to appear.

Abandonment option

This is an option, which gives a right to dispose an investment in a chance, when either market situation or inner situation causes a permanent deterioration of investment running conditions.

Option to change the scale

An option to change the scale allows to adapt the size of business to the current enterprise's requirements. We distinguish three types of the option: scale increase option, scale decrease option and a temporary business desist. An example of a temporary business desist is a renunciation of exploratory drilling within a specified territory but still retaining a prospection licence. It may be justified with e.g. expectation for new seismic research results.

Switching option (changing mode option)

This option allows changing a manner of operation, technology or products. That possibility gives an ability to adapt to the changing inner and outer conditions.

Growth option

This type of option is acquired by an enterprise through an investment in new market, product or technology. That kind of investment is often characterized by a negative NPV, what together with the use of a traditional valuation method would lead to the rejection of a project. However these investments give the enterprise prospects for the further development and growth, which can have a key significance to the enterprise policy in case of success. These options are of a great importance especially in branches with a high degree of risk and uncertainity and/or highly technologically advanced. The alternative of the increase option is an option of dividing into stages in which every next stage, leading to the growth of a scale of operation, is realized dependable on prior stages' results.

Compound Options

In the economic reality options connected with investments are often complex and multistage. Each of the initial options involves creating a series of new following options, and all the next can be a cause for another options to come into existence.

4. Pricing of real options

Just as in pricing of financial options, the models of real options pricing base on finding a mathematical model presenting an outline of future cash flows generated by the option. Two fundamental methods which are most often used are: the Black-Scholes model and the binomial tree model.

4.1. Black-Scholes model

The assumption on which the Black-Scholes model is based on, is that prices of underlying assets have disposition to a constant random process. Although the method is of a limited application in the area of real options pricing, it is still a theoretical basis for another options, including a binomial tree method.

The equation of Black-Scholes looks as follows [Hull, 1997]:

$$C = SN(d_1) - Xe^{-rt}N(d_2) \tag{1}$$

$$d_1 = \frac{\ln\left(\frac{S}{X}\right) + (r + 0,5\sigma^2)t}{\sigma\sqrt{t}} \tag{2}$$

$$d_2 = d_1 - \sigma\sqrt{t} \tag{3}$$

where:

C — value of the option,
S — current value of the project's cash flows,
X — cost of the exercising of the option,
t — time left to option expiry date,

σ — variability of the value of the project,
r — risk-free interest rate,
$N(d_1)$, $N(d_2)$ — value of a standardized normal distribution for variables d_1 and d_2.

Due to quite restrictive assumptions, the Black-Scholes model has a limited use in real options pricing in the oil and gas industry, because (Kobylańska et al., 2005):

a) it relates to so called European options (the date of exercise is the date of expiry) whereas in oil and gas investments most of the real options are American options.
b) it takes into account only one source of uncertainty, while real projects usually have many of them, and it assumes, that the price of option exercise is known and constant.
c) it does not take into account any lost takings, what eliminates the pricing of such options like: option to expand, option to change the scale, switching options etc.

Let's assume that a petroleum company thinks of a production from a potential unconventional gas deposit. A pilot project, whose task is to confirm the possibility of a profitable production, will last 2 years, and at the beginning of each quarter it will be necessary to spend 15 M PLN for it. After two years the company will either make a decision to start the full-scale investment or give it up. It is estimated that the income from the investment, discounted at the moment of a decision making (in two years) will come to 700 M PLN, and the essential outlays will come to 500M PLN. Risk-free interest rate (used to discounting expenditures) is 6%, and the income is discounted by interest rate of 15% (because of a higher risk).

A calculation of the investment NPV based on above-mentioned assumptions is presented in table 1.

TABLE 1

A calculation of the investment NPV

Time [years]	**0**	**0,25**	**0,5**	**0,75**	**1**	**1,25**	**1,5**	**1,75**	**2**
Outlays [millions of PLN]	15,00	15,00	15,00	15,00	15,00	15,00	15,00	15,00	500,00
Income [millions of PLN]									700,00
Discount coefficient	1,0000	0,9855	0,9713	0,9572	0,9434	0,9298	0,9163	0,9031	0,8900
Outlays PV [millions of PLN]	15,00	14,78	14,57	14,36	14,15	13,95	13,74	13,55	445,00
Income NPV [millions of PLN]	529,30								
Pilot project's outlays NPV [millions of PLN]	114,10								
Outlays NPV [millions of PLN]	559,10								
Investment NPV [millions of PLN]	**-29,80**								

The investment NPV is negative, what in case of a procedure of a traditional attitude to the profitability valuation means that the company is not going to accomplish a pilot project.

Expenses connected with a pilot project, however, can be treated as a cost of purchase of the option enabling starting full-scale investment. In this case we take into consideration the fact, that after the execution of a pilot project, and on the basis of received results, the decision about realization or giving the investment up will be taken. With this assumption the values of the parameters of Black-Scholes model are as shown in table 2. We assume the annual investment value volatility on the level of 40%, which results from volatility of the key parameters such as e.g. market price of natural gas. In this case the value of a call option (i.e. the possibility of execution of the full-scale investment) amounts to **156,34 M PLN.**

TABLE 2

Input parameters and calculation for the Black-Scholes model

Input parameters			
Investment NPV [millions of PLN]			529,30
Price of execution (investment's accomplishment expenditure) [millions of PLN]			500,00
Time left to the expiration date [years]			2
Option purchase price (pilot project outlays) [millions of PLN]			114,10
Interest rate			6,00%
Volatility			40,00%
Estimated options' value			
Call option's price [millions of PLN]			156,34
Put option's price [millions of PLN]			70,50
The rest of the model's parameters			
d1	0,595646161	N(d1)	0,724294
d2	0,029960736	N(d2)	0,511951

Because the option purchase price (discounted investment outlays for a pilot project) amounts to 114,1 M PLN, the surplus of the option value over its price equals 42,24 M PLN. In such a situation the execution of a pilot project is essential. After it is finished the decision about a full-scale investment implementation or its suspension should be made.

4.2. Binomial tree model

While pricing an exemplary investment using the Black-Scholes model we work on the assumption that the pilot project is being accomplished entirely and after it is finished the decision is made. In fact, the situation which is more probable is the one in which after each stage of a pilot project there is a possibility of giving it up and quitting the investment. The decision problem is more complex because there appear two options – purchase option (the option of continuation) and abandonment option. An abandonment option is an American option (can be accomplished in any moment before the expiration date), therefore the Black-Scholes model cannot be used in calculations. This type of options is most often priced using the binomial tree model (Winston, 2008).

In binomial trees, a model which is frequently used to estimate the future values is a geometric Brownian motion model. The model assumes that the asset's value changes in Δt time by an amount which is normally distributed with:

$$\text{mean} = \mu S \Delta t \tag{4}$$

$$\text{standard deviation} = \sigma S \sqrt{\Delta t} \tag{5}$$

where:

μ — momentary return of asset,
σ — momentary asset's value variation standard deviation,
S — present asset's price.

During constructing a binomial tree, the value of the analysed asset (S_1) after Δt time can take two values:

$$\text{With a probability of } p \; S_1 = S_0 * u \;\text{ for }\; u > 1 \tag{6}$$

$$\text{With a probability of } q = 1 - p \; S_1 = S_0 * d \;\text{ for }\; d = \frac{1}{u} \;\text{ and }\; d < 1 \tag{7}$$

where:

S_0 — initial asset's value,
S_1 — asset's value after Δt time,
u — value growth coefficient,
d — value drop coefficient.

Assuming geometric Brownian motion:

$$u = e^{\sigma\sqrt{\Delta t}} \tag{8}$$

Thus a risk-free probability comes to:

$$p = \frac{e^{r\Delta t} - d}{u - d} \tag{9}$$

where:

r — risk-free interest rate (most often the interest rate of government bonds)

TABLE 4

Input parameters

Interest rate	0,06
Volatility	0,40
Coefficient of growth in the next period	1,22
Coefficient of drop in the next period	0,82
Risk-free probability	0,49

The first phase of calculation is making a table with possible values of the investment during the analysed period of time (table 5).

The values of the investment in particular nodes are:

$$V(0,0) = NPV \text{ of investment profit} \tag{10}$$

$$V(i+1, j+1) = V(i,j) * u \tag{11}$$

$$V(i+1, j) = V(i,j) * d \tag{12}$$

where:

V — investment value,
i — column number,
j — line number.

TABLE 5

A calculation of a potential value of investment in particular quarters (millions of PLN)

	Period of time (quarters) – *i*								
j	0,00	1,00	2,00	3,00	4,00	5,00	6,00	7,00	8,00
8,00									2621,64
7,00								2146,42	1757,34
6,00							1757,34	1438,79	1177,98
5,00						1438,79	1177,98	964,45	789,62
4,00					1177,98	964,45	789,62	646,49	529,30
3,00				964,45	789,62	646,49	529,30	433,35	354,80
2,00			789,62	646,49	529,30	433,35	354,80	290,49	237,83
1,00		646,49	529,30	433,35	354,80	290,49	237,83	194,72	159,42
0,00	**529,30**	433,35	354,80	290,49	237,83	194,72	159,42	130,52	106,86

Afterwards we price the option of executing the full-scale investment (not taking into consideration the possibility of giving the pilot project up at the time of its duration). We start the calculation from the last column on the right and we move left. The value of the option in consecutive nodes looks as follows:

$$C(n,j) = \text{Max}\,[0, V(n,j) - E] \tag{13}$$

$$C(i,j) = \frac{p * C(i+1, j+1) + q * C(i+1, j)}{1 + r * \Delta t} - N, \text{ for } i < n,\ j \leq i \tag{14}$$

where:

E — option exercise price,
N — outlays for the next stage of a pilot project,
n — a number of columns/lines.

TABLE 6

A calculation of the option's value with no possibily of giving the investment up at the time of duration of a pilot project (millions of PLN)

	Period of time (quarters) – *i*								
j	0,00	1,00	2,00	3,00	4,00	5,00	6,00	7,00	8,00
8,00									2121,64
7,00								1639,05	1257,34
6,00							1242,62	931,34	677,98
5,00						916,77	663,13	456,94	289,62
4,00					648,73	442,27	274,69	138,95	29,30
3,00				432,80	269,62	142,88	51,30	-0,92	0,00
2,00			264,19	141,13	52,66	-1,97	-23,01	-15,00	0,00
1,00		136,50	48,67	-8,21	-36,68	-41,09	-29,78	-15,00	0,00
0,00	**42,09**	-16,84	-49,97	-61,46	-57,12	-44,34	-29,78	-15,00	0,00

The results of calculation are presented in table 6. The value of the option for conducting the investment full-scale is 42,09M PLN and is similar to the value received from the Black-Scholes model (these quantities will be closing to each other as the time difference diminishes).

A calculation of the investment value considering an abandonment option while the pilot project is implemented, is based on the assumption, that the decision about bringing the pilot project to an end is made in the moment when the value of the option of a specified node is negative. The calculations look as follows formula (13) is used *f* or $i = n$:

$$C(i,j) = Max\left[\frac{p*C(i+1,j+1)+q*C(i+1,j)}{1+r*\Delta t} - N, 0\right], \text{ for } i<n, j\leq i \qquad (15)$$

The results of the calculations are shown in table 7.

TABLE 7

A calculation of investment value, considering a possibility of investment abandoning during pilot project's implemention (millions of PLN)

	Period of time (quarters) – *i*								
j	0,00	1,00	2,00	3,00	4,00	5,00	6,00	7,00	8,00
8,00									2121,64
7,00								1639,05	1257,34
6,00							1242,62	931,34	677,98
5,00						916,77	663,13	456,94	289,62
4,00					648,73	442,27	274,69	138,95	29,30
3,00				432,85	269,74	143,11	51,76	0,00	0,00
2,00			265,80	144,26	58,75	9,87	0,00	0,00	0,00
1,00		143,50	60,99	13,23	0,00	0,00	0,00	0,00	0,00
0,00	**61,17**	14,31	0,00	0,00	0,00	0,00	0,00	0,00	0,00

The total value of options for execution of the investment and giving it up during the pilot project's implementation is 61,17 M PLN (so an abandonment option, by itself, is worth 19,08 M PLN). The example shows that owning an abandonment option may have an advantageous influence on the investment value.

5. Summary

Production from carbohydrate deposits (including unconventional ones) carries along many challenges, one of most significant of which is gaining the economical profitability of such a production. The profitability depends on an uncertain balance between costs and income gained from extracted carbohydrates sale, moreover, it demands using appropriate investment pricing methods.

The analysis of investment efficiency based on real options pricing enables overcoming coefficients limitations that work on a basis of discounted cash flows, although it's not their substitute but their complement. It puts together discounting methods and pricing of real options arisen during business running. The resultant is a more advanced tool providing decision-makers with detailed information. It gives a chance to avoid expensive errors at the stage of planning and investment's accomplishment, it also allows implementing investment projects, which are unprofitable in the light of traditional methods, but in fact make significant prospects of development for enterprises.

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