

REAL OPTIONS ANALYSIS IN THE ENGINEERING COMPANY PRACTICE

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Abstract

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In this paper, we deal with the real options analysis of selected investment projects. This approach is supplemented and compared to calculations of the net present value (NPV). Two research problems are analyzed: acquisition of the simulation software for the foundry industry in the sense of the expansive options and options on leaving the project in the case of acquisition of the spectrometer. For the option valuation, there were used analytical and numerical methods like the Black-Scholes model, binomial model and Monte Carlo simulations. In the case of binomial pricing model we used modification describing the behavior of the project's cash-flow (CF) due to capacity of the company, path-dependent addition and embedded option barrier. To extend the application of the real options analysis, we propose procedures for sensitivity analysis and option pricing based on Monte Carlo simulations for particular case of stochastic volatility.

Binomial lattice model, Monte Carlo simulation, net present value, real options analysis

The gap between business strategy and financial theory seems to be relatively extensive. The most important financial decisions of management, both in the amount of allocated resources and impacts on the future of the company, are still quite often performed without rigorous analysis. The standard ways of the effectiveness evaluation, for example the internal rate of return (IRR) and NPV methods, are shortsighted for these types of decisions. The strategic thinking on the subject of decision-making and budgets should be combined, especially in the cases where capital expenditures allow obtaining a strategic advantage.

We are synthesizing one of the modern approaches used in corporate finance – real options and their analytical potential – in determining the value of the investment projects of medium-sized engineering company (see further details in Klepáč, Kříž and Hampel, 2012a, 2012b).

American authors (for example Mun, 2002) converted the potential valuation of financial options to the valuation of real assets to bring together complex decision-making tasks and stochastic approaches of determination of objective

investment values and the associated cash flows. In general we can say that the real options method is applicable in industrial research and development, engineering and situations where projects can be divided into more technological phases, and the past influences the present, and thus the probable future. Nature of the system should be based on stochastically controlled parameters and a certain degree of uncertainty. There exists a large number of specialized approaches for solving of deterministic problems. They provide comparable, if not better, results than stochastic modeling (see Kislingerová, 2010).

Our approach is based on the concept in which the value of NPV is derived from the basal NPV, where value of flexibility is added to this quantity. This value is based on the flexibility of management decision and the stochastic nature of the dependent economic variables. The relationship can be expressed as follows (see Scholleová, 2007):

$$NPV(\text{with options}) = NPV + \text{flexibility (option)}.$$

MATERIAL AND METHODS

The main objective is to apply the real options approach to the two selected investments of medium-sized manufacturing company in Brno and then compare the results to the outputs generated from classical NPV concept.

The first research problem is to decide whether to buy or to rent the simulation SW (the Software) for foundry producing castings in three quality groups. The company was interested in the optimal solution of the timing of investments problem based on the situation in 2012 and outlook to 2016 (the SW has been rented for 300,000 CZK p.a. since 2011), when the company may finally purchase a license for the fixed-term price of 1.4 million CZK (European call option). The company implements the investment either at the end of the estimated period or during this period, but only if the CF reaches at least the level of the capital investment (American barrier option – expand option). The aim is to determine the value of the American option and to compare it with the European option.

Now we describe the second research problem. The company purchased and put into operation the equipment for the chemical analysis of metals in late 2010. This mobile spectrometer was acquired for a total amount of 1.088 million CZK. The company did not consider other devices before purchasing, since the contractor had excellent references and the device itself is a leader in its segment.

Multiple factors played an important role in deciding: increased image in relation to customers, growth of the productive potential – performing of the chemical analyzes for its own use, as well as for the needs of external entities. The price of chemical analysis is determined to 650 CZK for the analysis and 120 CZK for preparation of protocol. The task is to determine the value of the option in relation to the calculation of NPV when there is possibility to sell the device at 10 years after commissioning (European option) for 400,000 CZK, or any time up to 10 years (American option) or when CF decreases under barrier fixed at 500,000 CZK. The value of the option measures risk of the project abandonment (higher the value, higher the risk that the project would not generate sufficient CF).

Since we do not have enough information on past development, we can expect occurrence of the potential leaps in demand during the period; so we adjusted our valuation model for this eventuality using Poisson process technique. For project's valuation it is necessary to consider the needs of individual valuation models. Among the best known models can be included primarily Black-Scholes model, the n-step model (binomial for our case) and Monte Carlo simulation approach, which were also used in our particular application (for details see for example Hull, 2010).

The specifications of these models lie in the modifiability to a specific award, application requirements, and way of the asset value

development over time. The points of contact can be found in division of valuation into two dimensions: the first consists of simulations and predictions of the underlying assets development; in the second takes place valuation itself. The simplified algorithm can be described by the following steps:

1. Data collection and adjustment for the purpose of valuation.
2. Creation of a valuation model or modification of existing one.
3. Valuation.
4. Interpretation of the results for the purposes of real options analysis.

Input parameters of the valuation models include the initial value of CF, the discount rate, the time period, the expiration value, the level of barriers, the volatility and other parameters such as the intensity of the jump, the drift, etc. (Hull, 2010).

Binomial model is the representative of model in which the value of the underlying assets is determined in discrete sections. Apart from an initial point, the values are based on factors which increase or decrease the value of the assets compared to the previous point. Model is based on a perfectly recombining structure; or with respect to the intensity of outflows from the model (dividends, rent, sale of assets, stochastic jumps, etc.) is based on non-recombining structure (see Shreve, 2004). For our purpose we modified CRR model and get a probability weighted additive function of future values to fit European option paying dividends (see further details in Klepáč, 2012a).

Black-Scholes model (BS) is based on different foundations; asset value is generated according to continuous geometric Brownian motion with constant drift and volatility:

$$\frac{\Delta S}{S} = \mu \Delta t + \sigma \varepsilon \sqrt{\Delta t},$$

where ΔS is the change in the stock (or asset) price, S is the stock price, Δt is the change in time, μ is the drift term, σ is the volatility of the stock price, ε is a random variable from a standardized normal distribution. Option value is obtained on the basis of solution of partial differential equation (see Li, 2009).

Strictly speaking, Monte Carlo simulation is not a peculiar method of option valuation. It is a numerical procedure, which generates a large number of data sets according to a given continuous function. As an example we can state Brownian motion with stochastic jump

$$\frac{\Delta S}{S} = \mu \Delta t + \sigma \varepsilon \sqrt{\Delta t} + \kappa \Delta q,$$

$$\Delta q = \begin{cases} 0 & \text{with probability } 1 - \lambda \Delta t \\ 1 & \text{with probability } \lambda \Delta t \end{cases},$$

where κ is average jump size measured as a proportional increase in asset price, λ is rate at

which jumps happen per time unit, i.e. intensity of Poisson process. According to the purpose of the evaluation, we apply the valuation procedure for the transition to the option dimension and calculate the arithmetic mean to estimate the option value, which we discount to obtain the present value of the option. This method, despite its computational complexity, is usable for many specific tasks about options. It is usually possible to achieve these tasks in other ways, but the solution is too demanding (see Baxter and Rennie, 1996).

RESULTS AND DISCUSSION

The basis for the calculation of option values of both investment projects was to determine the input parameters. To obtain the mean CF for purchasing of simulation software we used the Monte Carlo simulation with 10,000 iterations in the software Crystal Ball. After performing Anderson-Darling test with Crystal Ball procedure we found out that gamma distribution approximates the input in the best way over other distribution functions. We use value of the Anderson-Darling test for this decision; this value can be considered for a particular probability distribution as a measure of similarity to the nonparametric density estimate included in Anderson-Darling test. We determined the resulting value equal to 465,261 CZK per year, the minimum value of the CF 128,531 CZK and the maximum reached value 1,139,217 CZK.

We set risk-free rate equal to 4.55%, which corresponds to the values of rates of 10-year government bonds at the beginning of 2011 (we relate calculations to this period). From the CF simulations we derived volatility based on the coefficient of variation at 39.7% p.a. From the basic calculation of NPV we calculated the NPV for each different period of expiration, when NPV decreases

with increasing distance of expiration time. This is due to the fact that when company buys software, it does not issue cash for rent anymore. By standard procedures of calculating NPV we got following values for expiration years 2016-2012: -178,420; 34,587; 244,647; 464,159 and 695,550 CZK.

For the company, it is logical to purchase software as soon as possible. Nevertheless, the basic NPV fails to satisfactorily reflect the need to cover the input costs of the investment because of assumed complexity of the task. Therefore, we switched to calculation by the binomial method in the form of modified Cox-Ross-Rubinstein model (a comprehensive model that directly calculates the total NPV of the project; for details about basic CRR see Hull, 2010)), when all the specified parameters (SW cease paying rent at expiration of the project, setting barriers early exercise) are met. For the initial evaluation and comparison, we used a basic application for calculating the value at expiration in 2016, the result is 50,776 CZK. When compared to the standard method of NPV, we see a substantial difference. When you move to the real options methodology, users must take into account that the value of the option cannot be negative. We are interested in which way and how much the project value changes in the application of other valuation conditions (growth parameter is 1.4873, decline is equal to 0.6723).

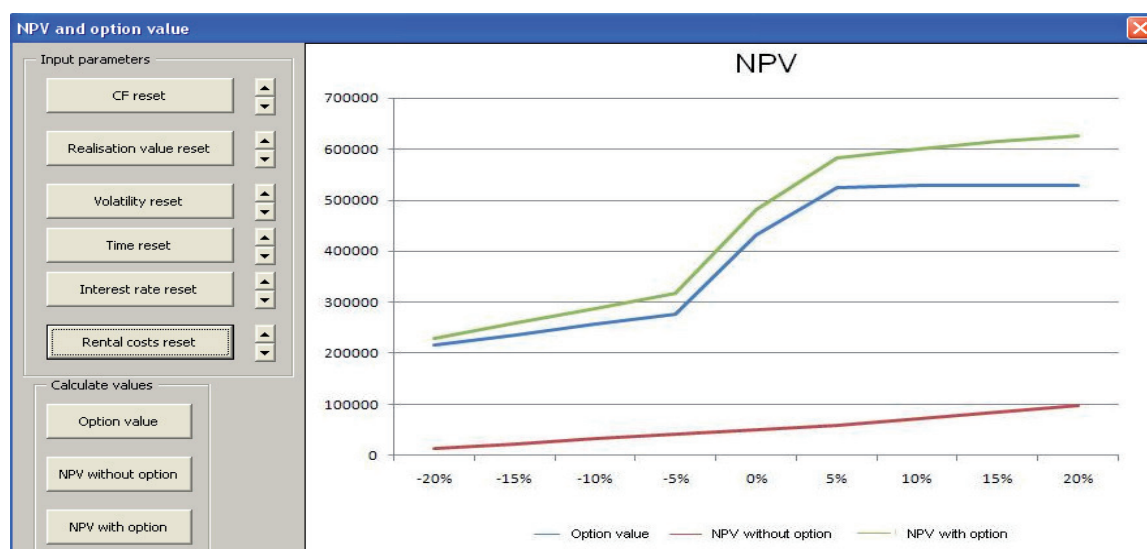
Model introduced in Fig. 1 detects a time in which most likely will be the first crossing of a frontier of the capital expenditures (dark gray cell) and therefore a full license of the software should be purchased in this time. This flexibility increases the value of the project:

For further analysis, we created an application for the sensitivity analysis in the Visual Basic for Applications (VBA) environment. There is possibility to simulate different scenarios, modify

2011	2012	2013	2014	2015	2016
					1
				1	2,835,304
			1	2,143,295	2,835,304
		0	1,451,287	2,512,859	1
	0	759,278	51,287	1	2,456,106
0	367,269	753,607	0	1,764,097	2,456,106
-24,739	756,682	0	723,152	2,150,528	1
564,791	0	348,341	1,412,181	0	2,076,908
	-11,928	824,289	0	705,663	2,076,908
	451,064	0	346,610	909,210	0
		882	398,026	0	1,000,982
		174,244	0	352,759	0
			13,693	0	0
			0	0	662,518
				26,504	0
				0	0
					339,315
					0

1: Binomial lattice model

Option value = NPV with option - NPV = 564,791 - 50,776 = 514,015 CZK.



2: Sensitivity analysis application

I: Projected CF and NPV (in mil. CZK)

CF/Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	NPV
CF.complete	-1.088	0.835	0.835	0.835	0.835	0.835	0.835	0.835	0.835	0.835	0.484	-0.125
CF.without investment		0.835	0.835	0.835	0.835	0.835	0.835	0.835	0.835	0.835	0.484	0.958
CF.operations		0.835	0.835	0.835	0.835	0.835	0.835	0.835	0.835	0.835	0.835	0.683

the value of the parameters and observe what implications/effects have these changes for the American option, NPV without options and the overall NPV, see Fig. 2. For the value of call options, the positive impact have a growth of the underlying asset's value, i.e. realized CF, and growth of volatility. Reduction of items such as rent, exercise price and time to expiration, increases option value in this case.

In the case of the spectrometer purchase, we used two approaches: Monte Carlo simulation with stochastic jumps and Black-Scholes model. Options can be defined as a put option (European and American) at project completion.

Estimated probability distribution of CF is triangular with parameters (min = 65, expected = 160, max = 300), and then the average value is 175 analyzes per year. The basis for the determination of these values was the result of the year 2011, when it was made in total 149 chemical analyzes. Performing basic calculations we come to the results shown in Tab. I. Total CF excluding optional termination of the project is negative. Calculating with purely operational variables, we can conclude that in this time horizon would not be beneficial to operate the device.

First, we created an iterative procedure based on Monte Carlo simulations with specific input values: projected CF value 683,000 CZK, $\sigma = 7\%$ p.a., time = 10 years/20 periods, jump size 5% p.a., Poisson process intensity 0.5 p.a. Further, the main algorithm is used and then transition to the option dimension

is performed. The outputs of the algorithms can be concluded in such a way, that the results are variable. This is due to used iterative technique; the values begin to converge to the BS model for the several thousands of iterations. Functionality of the application in Excel and VBA requires considerable demands on computer performance. The approximate results obtained for the model of Brownian motion with jump process are 2,614 CZK for the European option and 3,195 CZK for the American option. When we add the barrier equal to 500,000 CZK – premature realization of the option occurs at this point – the values are more unstable even with a relatively small number of iterations (100), they are in the range of 1,000 CZK to 20,000 CZK. From the formula for determining the value of the total NPV, we can determine the overall profitability of investment:

$$\begin{aligned} \text{NPV with European option} &= \\ &= \text{NPV without option} + \text{option value} = \\ &= -125,128 + 2,614 = -122,514 \text{ CZK} \end{aligned}$$

$$\begin{aligned} \text{NPV with American option} &= \\ &= \text{NPV without option} + \text{option value} = \\ &= -125,128 + 3,195 = -121,933 \text{ CZK} \end{aligned}$$

$$\begin{aligned} \text{NPV with Barrier option} &= \\ &= \text{NPV without option} + \text{option value} = \\ &= -125,128 + \text{NPV}(1,000; 20,000) = \\ &= (-124,128; -105,128) \text{ CZK} \end{aligned}$$

Total NPV is by no means positive. Therefore, we conclude that the investment is not beneficial for the company (in terms of 2011 within 10 years) even after counting the value of flexibility.

In SW DerivaGem, which contains several variants of calculating the value of the options, we got from the BS model the result for a European put option 591 CZK, but in the version implemented without stochastic jumps. In the case of adjustment of MC simulations algorithm we got values roughly between 15,000 and 20,000 CZK for the cases without the jumps; for American options higher – the differences are mostly due to the already mentioned low range of iterations.

The results of BS can be used to obtain the parameters of the project's sensitivity, which by their tendency analogously correspond to the model with jumps: Delta (change in CF) project is equal to -0.009941 ; Vega (volatility change) 576.34; Theta (per day change) 0.16; Rho (change in discount rate) -738.32 .

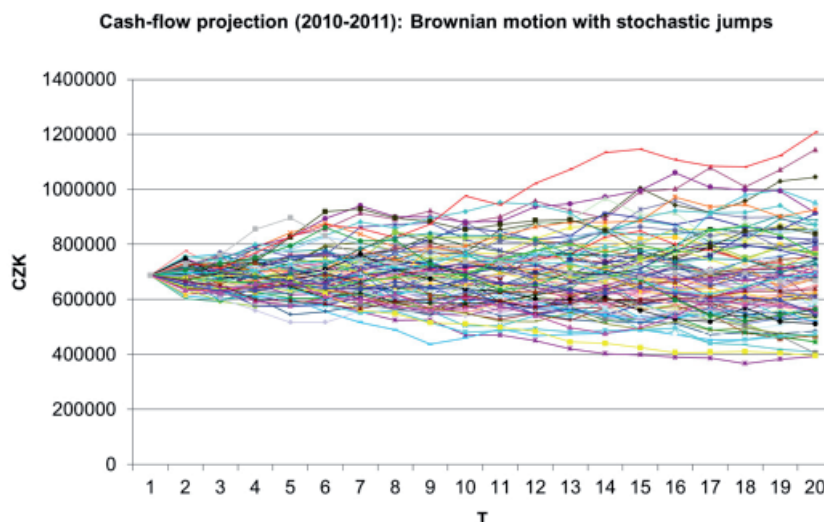
For the company, from the viewpoint of option valuation, early termination of the project is better than waiting until the expiration date on the end of the 10th year of investment age – it is expected from the very nature of the calculation of American options. From an economic perspective, however, the option value is established by inverse relationship to success of the project measured by the CF or NPV. It can also be said that the values of the option are an expression of the probability that the CF gets over time to a specified level (or barrier or project final expiration). Our experience shows that when the value of the option is low, then there is low also the probability of reaching these barriers, i.e. it can be assumed increase of operating CF contrary to expectations (see Fig 3).

CONCLUSIONS

After the real options analysis and valuation of flexibility in the decision-making process, it can be clearly said that the results provide expanded insight into the value-creating of investment projects. Compared to the NPV method, volatility component of CF brings closer particular tasks to the needs of a business practice, where it is necessary to deal with decision making under uncertainty. Results of analysis strongly depend on the reliability of the input data, since the sensitivity values for these options are high, especially for the estimation of the basic CF and a derivative volatility. For these estimates there are proven Monte Carlo simulation method for obtaining estimates of revenues, followed by additional calculations of CF and its variation quotient. The advantage of such simulations compared to variant calculation of CF (usually positive, neutral or negative) is covering a wider range of scenarios, and thus benefit from the results of more detailed statistical analysis.

The key factor of the valuation accuracy is the optimal selection of specific valuation models. Wrong class of valuation models or development function of underlying asset value may be too complicated for a selected task or even may bias estimates. The paper is based on methodological approach, where the value of the project consists of NPV and option value. In this sense we also construct the models. This makes possible to separate these components efficiently, regardless of whether we use the binomial method, Black-Scholes model or Monte Carlo simulation.

From the perspective of used methods, it can be said that the BS model is suitable mainly for rapid approximation of the value of European options. Numerical procedures were created for solving specific problems or we can solve these tasks by extending existing models. Simulation techniques are highly flexible and depend only on the user's



3: Simulation Monte Carlo on CF projection

ability to model a real system. It is necessary to keep in mind that the possible change in the initial entry may have an unpredictable effect on the final value, particularly in the case of "simulations of simulations"; this can make analysis of the results problematic.

A sensitivity analysis plays significant role in real options methods. That allows quantifying the intensity and tendency of the influence of the independent variables on the option value. We can

say that for estimates of less complex models can be used for example function Spider-chart software Crystal Ball, which clearly shows the development of option value with changes in the dependent variables for a selected percentage. Another alternative is to create your own application, as we do, or to use software DerivaGem that can calculate the sensitivity parameters for basic models for in the sense of partial derivatives (so-called Greek letters).

SUMMARY

The paper deals with the modern way of investment decisions – real options methodology, where the main focus is on tapping the value of flexibility – the option to change during the project. The basis for processed analyses was data obtained from a major engineering company from Brno. Specifically, these were cases of deciding on the optimal timing of acquisition of simulation software which is used in production of castings (American expansion option with a barrier), and the case of premature sale of the spectrometer for chemical analysis of metals (American and European put options on completion of the project, with and without barriers). For the option pricing were used analytical and numerical methods such as binomial model, Monte Carlo simulations (based on geometric Brownian motion with stochastic jump) and the Black-Scholes model. Individual tasks required a modification of the basic pricing models due to production capacity constraints, character of development predicted sales, contemplated barriers and associated path-dependent nature of valuation.

In the case of purchase / lease of simulation software, we came to the conclusion that it is clearly worth purchasing a full license (American call option) earlier than initially stated – reducing the cost of renting is a significant motif, which can be enhanced by the positive evolution of CF (American expansion option has a value of 514,015 CZK; the total NPV of the project is 564,791 CZK).

The situation on the second task, i.e. the acquisition of spectrometer and an evaluation of its economic contribution, is more complicated. Management decisions are made on several variants of development, which surround the sale of equipment if CF falls below the barrier or the sale of equipment at the end of a predetermined period, respectively. The key parameter on which depends the final decision on the former sale is the potential drop of CF, which would further reduce even so negative basic NPV (–125,128 CZK). Calculated values of this option cannot reverse this: NPV with European option (at expiration date) is equal to –122,514 CZK; NPV with American option (at expiration date) is equal to –121,933 CZK and NPV with Barrier option is equal to –125,128 + NPV(1000, 20000) = (–124,128; –105,128) CZK. The low value of the option indicates low probability of potential sinks below the selected CF barrier or expiration value. This is despite the negative total NPV positive finding that could lead to the positive total NPV in the case of the investment horizon extension, that could probably generate bulkier base NPV.

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