Modified Real Options Valuation for Developing Product-Type Innovation Strategies

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Abstract

Using the Black-Scholes Option Pricing Model (OPM) that has already become classical for evaluating the market value of a real option is problematic since it includes standard deviation of contractual revenue performance, which is impossible to predict accurately. In addition, the OPM is applicable to European options only. But we assume adequate flexibility of an option contract, which implies a possibility of early exercising the option. In this connection, there appears a task for developing and applying another model. In this quality, we suggest using a binomial option-pricing model that is modified for increased risk conditions.

At present time, very close attention is devoted to investment in innovative development of industrial enterprises. In the post-crisis period, conventional approaches for investment by no means always result in an expected positive result; therefore, it is necessary to search for new non-standard methods and instruments for managing innovative activities of enterprises and use up-to-date management technologies operating in the commercial environment.

Investments and innovations are two inextricably intertwined areas of economic activities. The innovative activities of industrial enterprises in the post-crisis period created a specific requirement that cannot be met using conventional investment instruments and methods of evaluating their efficiency. This is a requirement for adopting investment decisions under uncertainty caused by rapid changes in the activity environment, a requirement for reducing the risk of loss of competitiveness in future due to lack of rights for innovation utilization or any other rights relating or not relating to property. Besides, it is not known to what extent a particular factor will become significant in future. It is required to find a possibility to neutralize the risk of investment in innovative activities of companies spending for this purpose an adequate amount.

One of the areas of neutralizing the said risks, which is not an alternative to prediction development but a supplement to it, includes creating methods of evaluating investments and innovative indicators adapted to activities of companies in rapidly changing conditions of the external economic environment. The most promising area of application of such methods includes innovative activities and the sphere of real investment with most serious risks and uncertainties. In this sphere of activities, the conventional methods of evaluating the efficiency of investments often produce negative results, which, on the one hand, is one of the reasons for refusal from investment in various facilities, and on the other hand, often fails to reflect actual efficiency of projects.

For evaluating investment innovative projects with due consideration of the possibility to modify the conditions of implementing such projects and adopt relevant decisions, it is suggested to use tools of the real options valuation (ROV) method.

Real options afford the opportunity to modify and adopt decisions in future in accordance with coming information. This is relevant for evaluating investment innovative projects in the dynamic and rapidly changing external environment of company activities and enhancing the flexibility in making managerial decisions. It makes sense to use the ROV method provided that:

- the company managers are capable of making flexible managerial decisions upon appearance of new data relating to the project;
- the project result is to a large extent dependent on decisions taken by the company management;
- the project result is subjected to a high degree of uncertainty;
- while evaluating the project using the discounted cash flow method, the net present value (NPV) is negative or somewhat larger than zero.

It is also important that the use of the real options instrument enables to attract investments for creation and commercialization of an innovative product where no result of the project implementation is yet clear to the last, and any failure to participate in the project threatens a loss of the company competitiveness in future.

Let us consider an alternative of attracting investments 'for a product' in the automobile industry. Let us assume that OAO KAMAZ is developing a new model of a truck on the basis of the latest model 'KAMAZ-5460 Truck Tractor', but at the same time the company is not sure that this model will be quickly demanded in the truck haulage market. Therefore, the company neutralizes its commercial risks by selling options that may be converted into firm contracts in case of increasing the volume of freight traffic using this truck model. As an investment instrument acquired by an investor, these options may be profitably resold in future.

While making a decision on research and development (R&D), the company management (researcher - developer - manufacturer) and a prospective buyer (investor) are in highest uncertainty in respect of implementation and commercial prospects. Following the research, the commercial prospects of the initial project will become more definite, and it will be easier to take a decision. However, this definition may act both against the investor who will finance additional research and against the holder of rights for the previously obtained result (researcher) who may conduct the research at its own cost without involving the investor.

If the research is financed by a prospective buyer of rights for the previously obtained result, and there is a high commercial attractiveness of the result, then the price of the rights for this result will immediately increase. It turns out that financing the additional research, the prospective buyer will make its position worse. In a similar way, the researcher may make its position worse if it carries out this research at its own cost, and the result happens to be negative.

The situation changes for the better if expenses for any additional research are considered as acquisition of a favorable opportunity in the form of an option - a right without any liability. For example, a potential buyer of rights for the previously obtained result agrees to finance additional research and receives in return a right to choose after its completion between acquisition of exclusive rights at a previously fixed price and resignation of such transaction. It is important that the price of a potential transaction is fixed in advance. At the same time, the price may have a broad meaning, i.e. it may not necessarily denote a fixed monetary amount. The payment itself is not necessarily made in cash. For example, a new option for R&D on a subject defined by the contractor or any other resources and preferences having a real value may be provided as a payment.

Expenses for additional analyzing R&D and commercial effectiveness, for instance, of 15 batches of trucks may be planned in a lump sum of money taking them at the option market value. For an investor, it will be a call option, and then it is possible to estimate its market (current) value using an appropriate calculation model. The attained value may be used as the cost of managerial option to estimate the real NPV of an innovative project:
Real NPV = Conventional NPV + Cost of managerial option.

Using the Black-Scholes Option Pricing Model (OPM) that has already become classical for evaluating the market value of a real option (Black, Scholes, 1973) is problematic since it includes standard deviation of contractual revenue performance, which is impossible to predict accurately. In addition, the OPM is applicable to European options only. But we assume adequate flexibility of an option contract, which implies a possibility of early exercising the option. In this connection, there appears a task for developing and applying another model. In this quality, we suggest using a binomial option-pricing model that is modified for increased risk conditions.

For the convenience of further considerations, let us introduce some designations:

S_t – contractual market price at the end of period t (RUB);
r_u – rate of the highest inflation predicted by an investor for period t (%);
r_d – rate of the lowest inflation predicted by an investor for period t (%);
r_f – risk-free rate (refinancing rate) for period t (%);
i – rate of inflation predicted by a company selling a real option (researcher) and fixed in a contract for period t (%);
K_t – strike price at the end of period t (RUB);
C_t – option price at the end of period t (RUB);
C_u – option price in case of maximum inflation growth (RUB);
C_d – option price in case of minimum inflation growth (RUB);
C^N – price of 'live', i.e. unexercised, option (RUB);
C^A – price of 'dead', i.e. exercised, option (RUB);
C_u^N – price of 'live' option in case of maximum inflation growth (RUB);
C_d^N – price of 'live' option in case of minimum inflation growth (RUB);
C_u^A – price of 'dead' option in case of maximum inflation growth (RUB);
C_d^A – price of 'dead' option in case of minimum inflation growth (RUB).

Let us consider the suggested model using the listed designations. At present time, let an investor and a seller of a real option reason in the following way:

1. The investor believes that the minimum annual rate of inflation in Russia will be 5%, and the maximum rate will be 55%.
2. The real option seller predicts the annual inflation rate of 30% and prescribes it in the contract.

That done, the option contract is drawn up in view of the following terms:

1. Actual market price of the contract: S_0 = 15 billion rubles.
2. Actual contract execution price: K_0 = 15 billion rubles.
3. The total contract term is two years.
4. The option contract is an American-type contract, i.e. it may be executed at any time during its validity period.
5. The contract implies modification of its execution price (K_t) every period t, depending on inflation i for the relevant number of periods.

From the first two conditions of the contract, it follows that its conventional NPV = $S_0 - K_0$ = 15 billion rubles – 15 billion rubles = 0.

Let us determine what real NPV will be with account of the contract option value.

In order to estimate the real option value in each year of the total period, it is required to primarily determine model input parameters. As a refinancing rate, let us take its present value - 7.75%. The result is that
$r_u = 0.55$; $r_d = 0.05$; $r_f = 0.0775$; $i = 0.3$.

Then we obtain a binomial process of the contract market price modification (S_t) for two years as presented in Figure 1. The same figure shows a change in the strike price (K_t) at annual rate i.

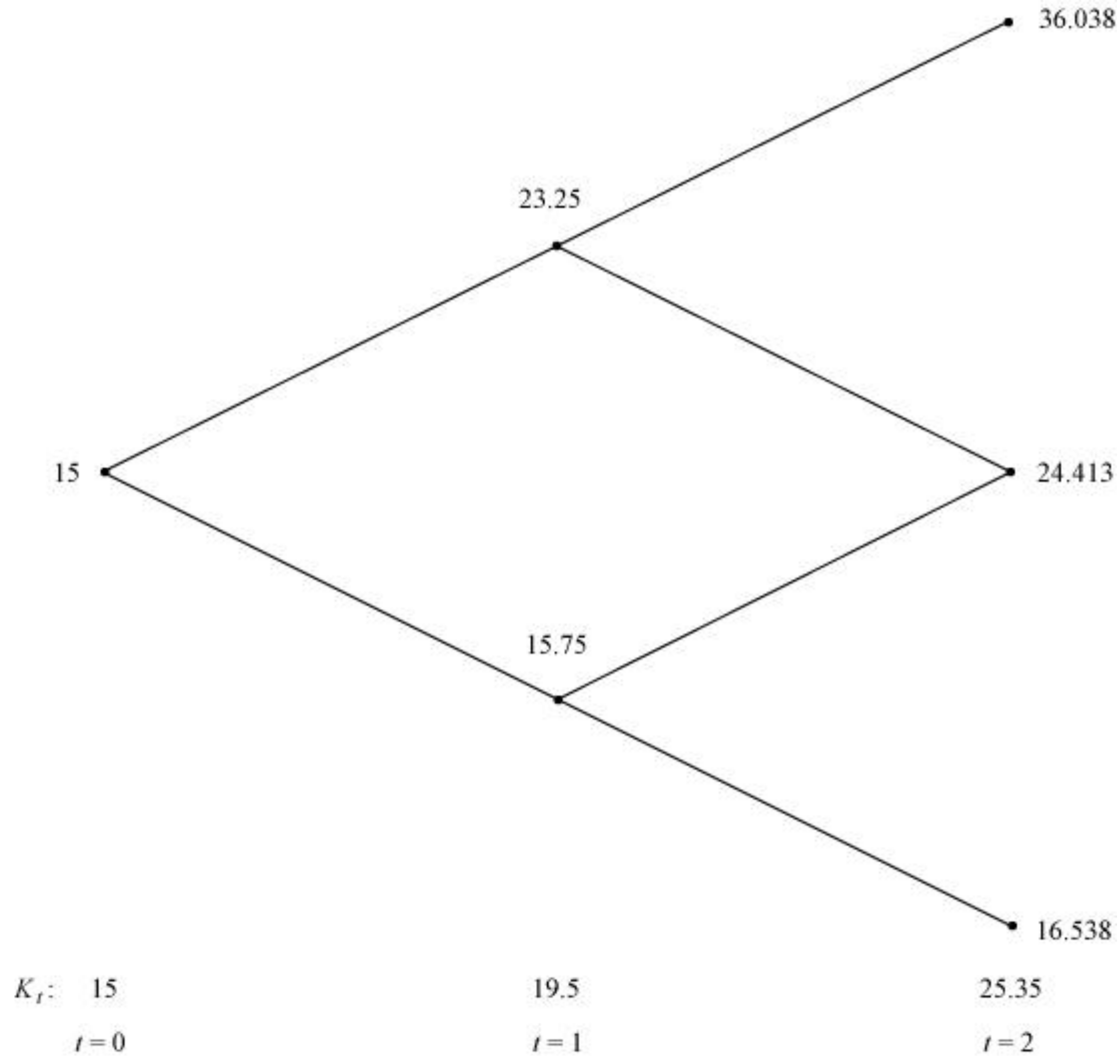

Fig. 1. Change in the Contract Market Value for Two Years (billion rubles)

Based on the classical binomial model (Kruschwitz, 1999), the price of a 'live' option may be calculated according to the formula

$$C_t = \frac{1}{1+r_f}\left(pC_{t+1,u} + (1-p)C_{t+1,d}\right),$$

where p - pseudoprobability determined by the equation

$$p = \frac{r_f - r_d}{r_u - r_d}.$$

As opposed to the usual mathematical probability of event occurrence, the value p is not directly valuated. It may be calculated on the basis of profitabilities r_u and r_d and risk-free interest rate r_f. To do this, neither preference structure of the market participants, nor information on their individual perceptions of probabilities is required. They keep in the background, and therefore, p may be only interpreted as pseudoprobability.

Consequently, it is possible to estimate the option value in any period t if $C_{t+1,u}$ and $C_{t+1,d}$ are known in the following period $t + 1$.

Using the formula for C_t, we may consecutively calculate prices of the 'live' option starting from the second year and ending by the present time (Figure 2).

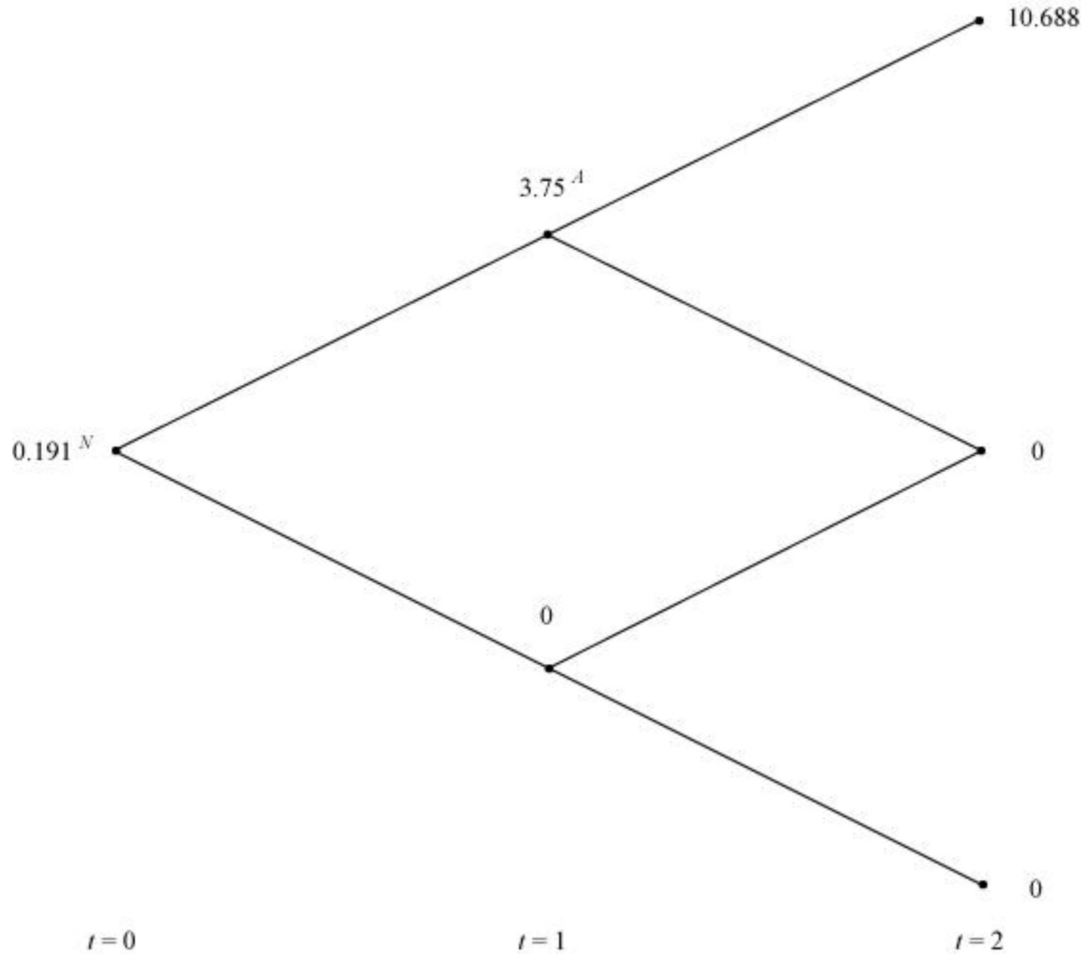

Fig. 2. Change in the Real Option Price for Two Years (billion rubles)

Since we consider a call option, then in the second year (t = 2), its price should be calculated according to the formula

$$C_2 = \max(S_2 - K_2, 0).$$

The same principle should be used to calculate the price of the 'dead' option in the first year (t = 1).

Let us consider the method of calculating the price of the 'live' and 'dead' option in each year. To do this, it is primarily necessary to calculate pseudoprobabilities p and $1 - p$:

$$p = \frac{0.0775 - 0.05}{0.55 - 0.05} = 0.055; \quad 1 - p = 0.945.$$

Then according to the data provided in Figures 2 and 1, we obtain as follows:

$$C_{1,u}^{N} = \frac{1}{1.0775}(0.055 \cdot 10.6875 + 0.945 \cdot 0) = 0.545534; \quad C_{1,u}^{A} = 23.25 - 19.5 = 3.75.$$

In year t = 1, as the option price, one should select its maximum value in each situation. In this case, in the situation of maximum inflation growth, the 'dead' option is more expensive, that is why its price should be selected for the calculations in the previous year t = 0.

The situation of the minimum inflation growth in year t = 1 subject to the data provided in Figure 2 should not be calculated as the option prices in year t = 2 used to calculate the relevant option price in year t = 1 are equal to zero.

Then we have the following at the beginning of the period:

$$C_0^N = \frac{1}{1.0775}\left(0.055\cdot 3.75 + 0.945\cdot 0\right) = 0.191415.$$

The last figure denotes the real option price in billion rubles at the present time.

It is not difficult to note that in the first year in the situation where the option price is equal to zero, the 'dead' option is more expensive, and this means that in this situation, it is more profitable for an investor to exercise the real option in advance.

Should the investor wish to calculate its actions throughout shorter time intervals, which would enable it to attain even greater flexibility in making managerial decisions, let us construct the same model with the same input parameters for two events: 1) six-month periods and 2) quarterly periods.

For six-month periods, the model input parameters will change as follows:

$$r_u = \sqrt{1.55} - 1 = 0.24499; \quad r_d = \sqrt{1.05} - 1 = 0.024695;$$
$$r_f = \sqrt{1.0775} - 1 = 0.038027; \quad i = \sqrt{1.3} - 1 = 0.140175 \ .$$

Then we obtain a binomial process of the contract market price modification (S_t) for four six-month periods as presented in Figure 3. The same figure shows a change in the strike price (K_t) at six-month rate i.

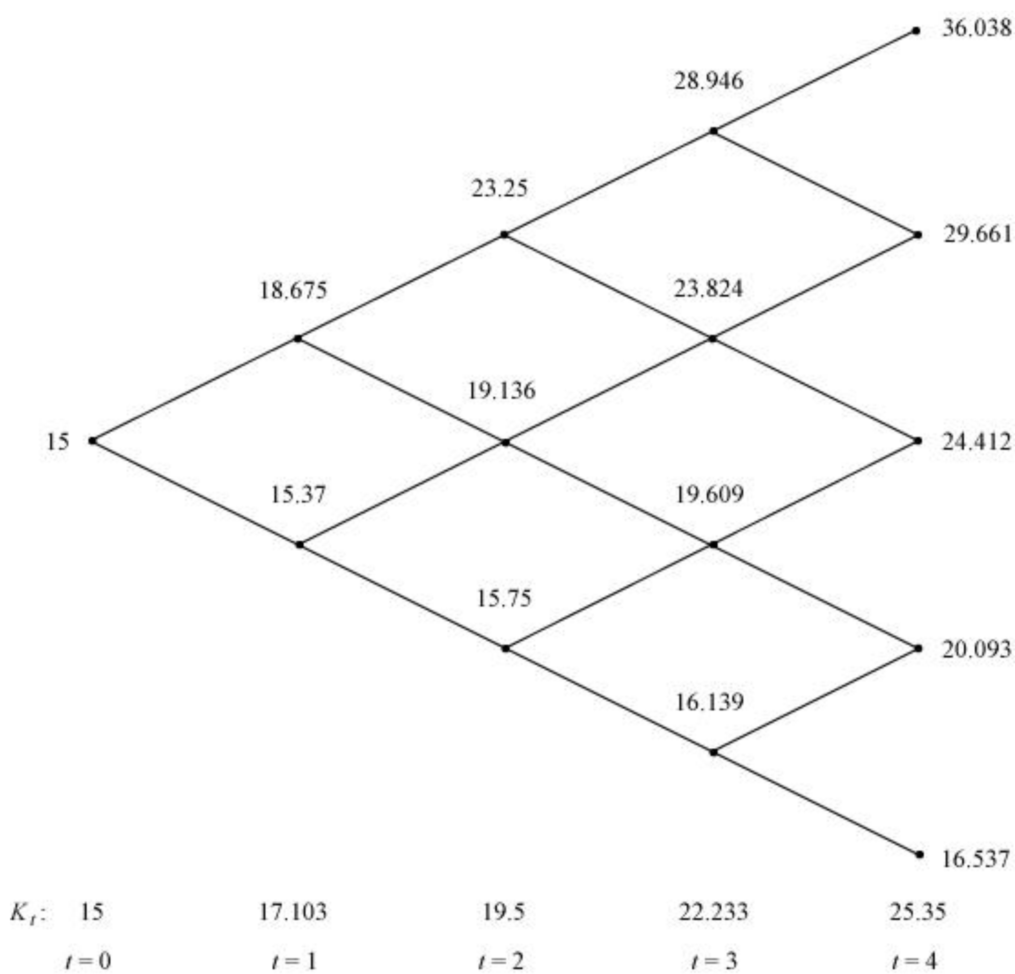

Fig. 3. Change in the Contract Market Value for Four Six-Month Periods (billion rubles)

Using the formula for C_t, we may consecutively calculate prices of the 'live' option starting from the fourth six-month period and ending by the present time (Figure 4). To do this, it is primarily necessary to calculate pseudo-probabilities p and $1 - p$:

$$p = \frac{0.038027 - 0.024695}{0.24499 - 0.024695} = 0.060519; \quad 1 - p = 0.939481.$$

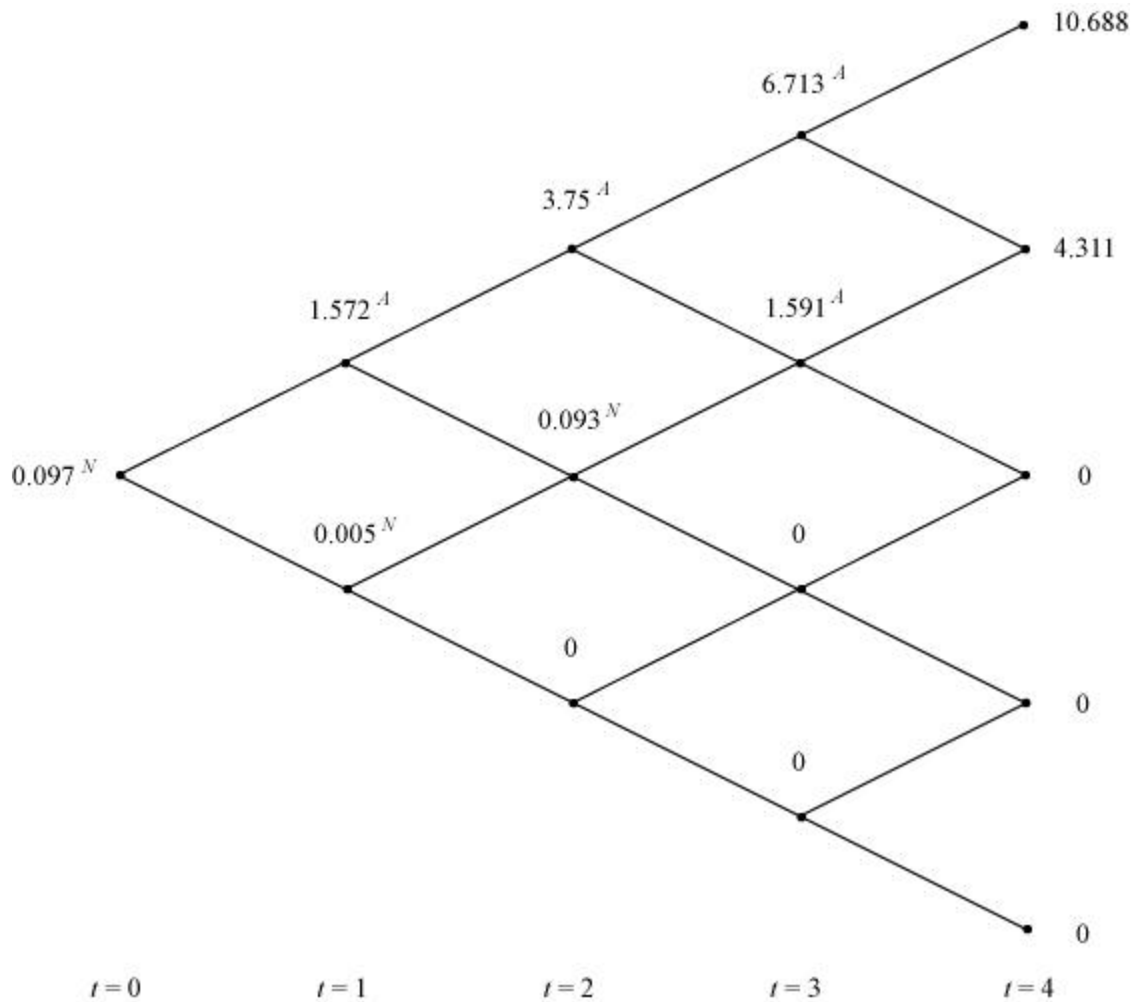

Fig. 4. Change in the Real Option Price for Four Six-Month Periods (billion rubles)

Then, according to the data from Figures 4 and 3, we obtain that in the third six-month period in the situation of three-fold maximum inflation growth

$$C^N_{3,u^3} = \frac{1}{1.038027}(0.060519 \cdot 10.687543 + 0.939481 \cdot 4.310879) = 4.524727;$$

$$C^A_{3,u^3} = 28.946019 - 22.233396 = 6.712623,$$

in the situation of two-fold maximum inflation growth and one minimum inflation growth

$$C^N_{3,u^2d} = \frac{1}{1.038027}(0.060519 \cdot 4.310879 + 0.939481 \cdot 0) = 0.251333;$$

$$C^A_{3,u^2d} = 23.82416 - 22.233396 = 1.590764.$$

The other two situations in the third six-month period subject to the data provided in Figure 4 should not be calculated as the option prices in the fourth six-month period used to calculate the relevant option prices in the third six-month period are equal to zero.

For further calculations in the second six-month period, the prices of 'dead' options in the third six-month period should be used as maximum ones since according to the data from the example, there is always a possibility to implement the option contract ahead of time. Then in the second six-month period:

$$C_{2,u^2}^{N} = \frac{1}{1.038027}(0.060519 \cdot 6.712623 + 0.939481 \cdot 1.590764) = 1.831102;$$

$$C_{2,u^2}^{A} = 23.250002 - 19.499985 = 3.750017.$$

The 'dead' option should be selected for calculations in the first six-month period.

$$C_{2,ud}^{N} = \frac{1}{1.038027}(0.060519 \cdot 1.590764 + 0.939481 \cdot 0) = 0.092745;$$

$$C_{2,ud}^{A} = 0.$$

The 'live' option should be selected for calculations in the first six-month period.

In the first six-month period:

$$C_{1,u}^{N} = \frac{1}{1.038027}(0.060519 \cdot 3.750017 + 0.939481 \cdot 0.092745) = 0.302573;$$

$$C_{1,u}^{A} = 18.67485 - 17.370425 = 1.572225.$$

The 'dead' option should be selected.

$$C_{1,d}^{N} = \frac{1}{1.038027}(0.060519 \cdot 0.092745 + 0.939481 \cdot 0) = 0.005407;$$

$$C_{1,d}^{A} = 0.$$

The 'live' option should be selected.
Finally, at the beginning of the period:

$$C_{0}^{N} = \frac{1}{1.038027}(0.060519 \cdot 1.572225 + 0.939481 \cdot 0.005407) = 0.096557.$$

The last figure denotes the real option price in billion rubles at present time.
For quarters, the model input parameters will change as follows:

$$r_u = \sqrt[4]{1.55} - 1 = 0.115791; \quad r_d = \sqrt[4]{1.05} - 1 = 0.012272;$$

$$r_f = \sqrt[4]{1.0775} - 1 = 0.018836; \quad i = \sqrt[4]{1.3} - 1 = 0.06779 \ .$$

Then we obtain a binomial process of the contract market price modification (S_t) for eight quarters as presented in Figure 5. The same figure shows a change in the strike price (K_t) at quarterly rate *i*.

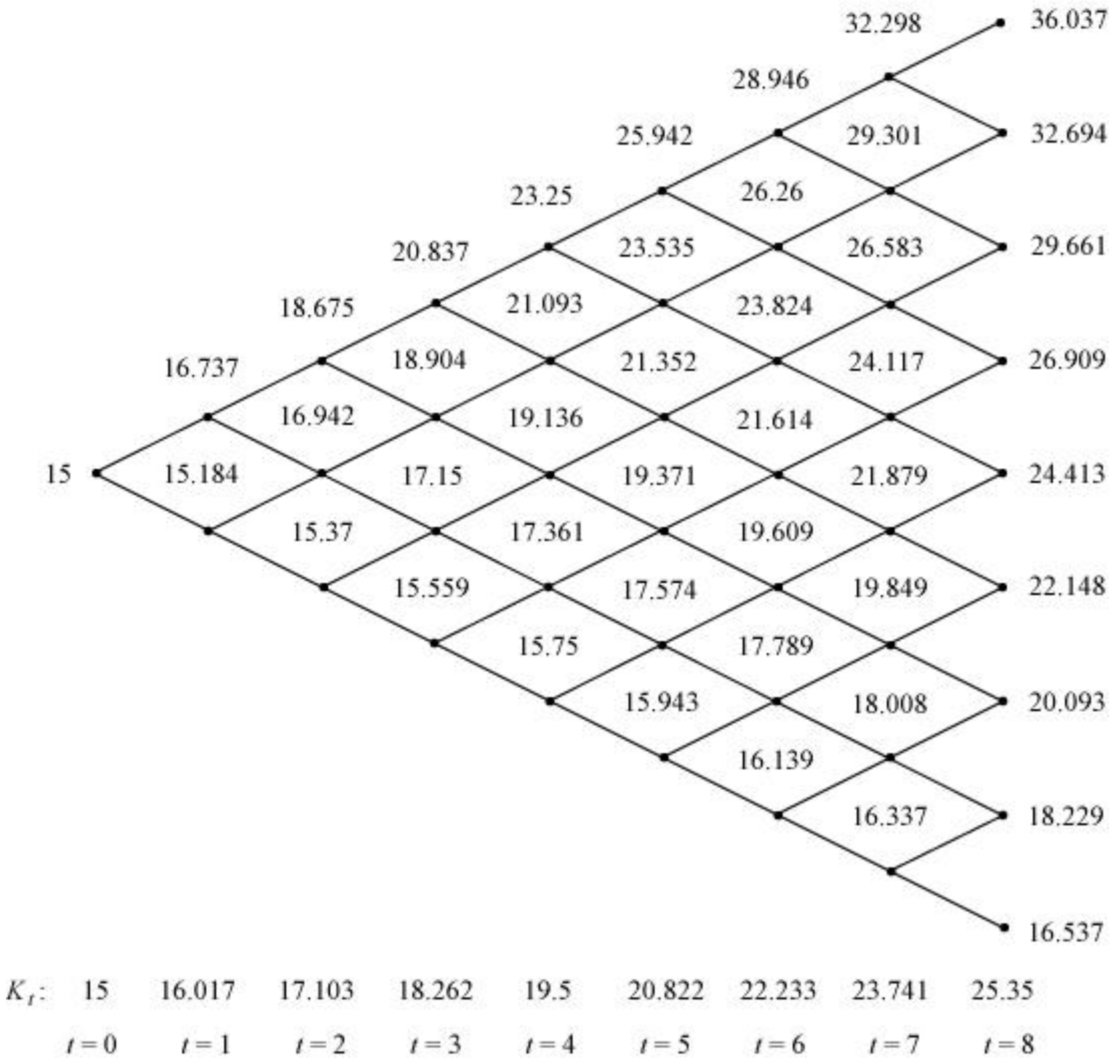

Fig. 5. Change in the Contract Market Value for Eight Quarters (billion rubles)

Using the formula for C_t, we may consecutively calculate prices of the 'live' option starting from the fourth six-month period and ending by the present time (Figure 6).

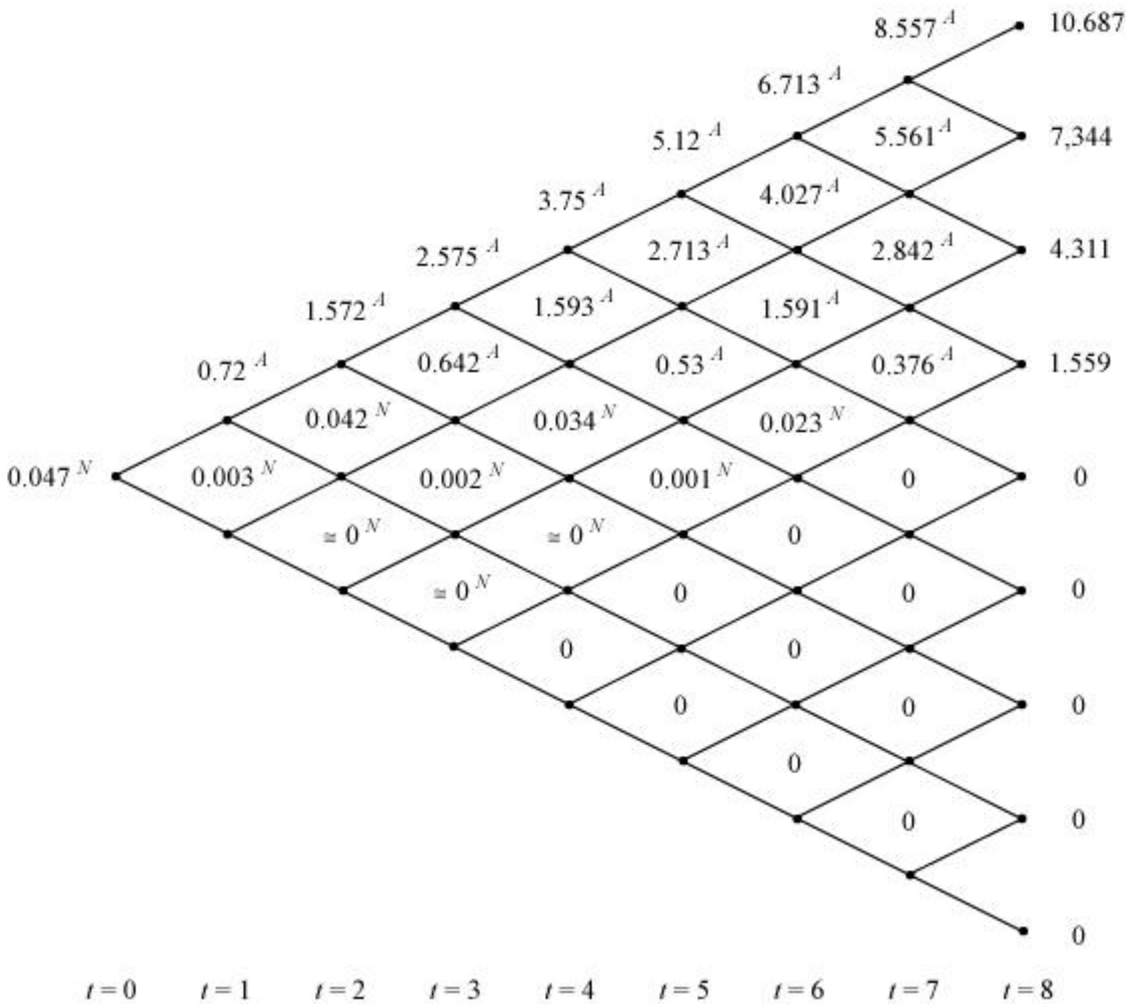

Fig. 6. Change in the Real Option Price for Eight Quarters (billion rubles)

Then according to the data from Figures 6 and 5, we obtain as follows:

$C_0^N = 0.047336$.

The last figure denotes the real option price in billion rubles at present time.

The practical value of such calculations consists firstly in the fact that it is eventually possible to calculate the real option price at present time, and secondly in the fact that according to the data from Figures 2, 4 and 6, it is possible in each period *t* to adopt an optimal decision as to whether the option should be exercised ahead of time, or it would be better to wait. Indexes *A* in Figures 2, 4 and 6 designate points where the 'dead' option is more expensive, i.e. situations in which it would be better to exercise the option ahead of time, and indexes *N* designate points where the 'live' option is more expensive, i.e. situations in which it would be better to wait.

An important result also includes the fact that the real NPV of the contract under review is positive unlike the conventional NPV. For instance, for an event of analyzing annual time intervals (Figure 2):

Real NPV = Conventional NPV + Cost of managerial option =
= 0 + 0.191415 = 0.191415 (billion rubles).

It is a reminder that we are considering the cost of a managerial (real) option consisting of expenditures for additional analyzing R&D and commercial effectiveness of 15 batches of new models of the KAMAZ trucks. If this cost grows in course of time, then it is possible to increase the expenditures in proportion to the difference between the new and old option value. It is also possible to resell the option at a profit to another investor.

Furthermore, while comparing the real option prices at present time in the three cases: 1) annual periods of time, 2) six-month periods and 3) quarterly periods, one can make a conclusion that a great time flexibility of a contract leads to reduction of uncertainty, which eventually results in decreasing the real option price. This result is without prejudice to the classical theory of options.

With all benefits of real options, using them during an investment projection implies certain difficulties that are associated with the necessity to modify the enterprise management strategy. Let us specify drawbacks of the real option valuation (ROV):

1. A groundless approach for the cost of creating and maintaining real options and a wrong estimate of probabilities may adversely affect the enterprise development.
2. The enterprise's adherence to excess flexibility in making decisions may lead to frequent reviews of plans, loss of development orientation and failure to perform strategic plans.
3. Implementing the real option model requires modification of the enterprise internal culture and approaches for doing business. Where a conventional decision on the commencement of a project is made, it is extremely unprofitable to stop the already started project in most cases. Where a project is launched on the basis of ROV, it is required to take project decisions again in certain points of time, up to the point of a decision on its closure.

Finally, let us formulate the obtained practical conclusions:

1. The Black-Scholes Option Pricing Model (OPM) is not applicable for evaluating real options under conditions of limited information on predictable business profitability since it includes standard deviation of contractual revenue performance, which is impossible to predict accurately. In addition, the OPM applies to European options only. But in practice, we need adequate flexibility of an option contract, which implies a possibility of early exercising the option.
2. To solve this problem, we propose to use a binomial model modified for conditions of high investment risk.
3. The first modification of the binomial model consists in changing the real option strike price in a certain period of time, depending on the inflation rate for the corresponding number of elapsed periods.
4. The second modification consists in a practical possibility to trace periods of time that are favorable for early exercising of the real option.
5. A great time flexibility of an option contract leads to reduction of uncertainty, which eventually results in decreasing the real option price. This result is without prejudice to the classical theory of options.

In the forming situation of doing business at present time, it is required to have investment mechanisms for operation of companies under condition of uncertainty created by the lack of information on potential changes in properties and value of an investment object, such as a technology, a product or a software solution as well as conditions of doing business. The most attractive from this point of view are mechanisms based on the use of real options. Enhancing the option application area to invest in perspective innovative projects will allow creation of a number of intellectual advantages in forming the innovative economy.

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