Cluster Innovation Strategy Risk Management Using a Real Put Option to Abandon a Strategy

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Abstract

The subject of investigation includes the issue of adjusting an innovation strategy of an industrial innovation cluster under uncertain behavior of the external and internal environment. With that in mind, a possibility is regarded as to abandon the cluster strategy that has already been initiated and even, subject to the relevant threats of the regional economic environment, to abandon it and switch to another strategy. In this case, the strategy is set in the form of an optimal portfolio of major companies representing the respective economic sectors of a region, following which the cluster strategy is investigated for any possibility to abandon its implementation at any time within the planning horizon, other than the last year. In order to manage the risks of the industrial innovation cluster evolution, this article employed a real put option technology to abandon the strategy. As a function that most adequately characterizes the present state and prospects for the development of individual companies and industries, it is possible to use a level of market capitalization by value. And as a cash flow of industrial projects, it is possible to use an incremental cash flow representing a difference between the market capitalization values from time to time. This cluster evolution risk management philosophy utilizing the real option techniques eventually allows to adjust the global regional strategy when required.

Keywords: clusters, innovation strategy, real options, put option

JEL Classification: C54, E27, G32, L16, O21

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1 Introduction

Evolution of industrial innovation clusters is a complicated and time-consuming process. Management of such process by the government and informal groups of leading companies of a cluster is integral to the cluster successful development. In this regard, it is important to plan its development, which implies, first and foremost, the development of the cluster innovation strategy. For that end, predictive foresight methods are usually used in real-case scenarios (Martin, 1983, 1989, 2010; Chernykh, 2012; Kalyuzhnova and Verkhoturova, 2013; Calof, Richards and Smith, 2015; Kharitonov, Kurelchuk and Masterov, 2015).

However, the cluster innovation strategy itself is not an eventual result of analyzing and planning the cluster evolution. Under current conditions of higher risks of the Russian economy as a developing market (Limitovsky, 2008), it is relevant to consider the opportunities of adjusting the strategy that has already been initiated and even, subject to the relevant threats of the cluster economic environment, of abandoning it and switching to another strategy.

The business has already tried and tested a considerable amount of such technologies making it possible to take flexible managerial decisions. They are called real options (ROV) (Myers, 1977; Damodaran, 2002; Roche, 2005; Limitovskiy, 2011; Klychova et al., 2016). The most common of them are deemed to be options to scale down and to abandon a business, options to develop and to expand an experience, options to switch and to suspend a business, options to delay a project start, and options on already existing options (Limitovskiy, 2011).

As can be seen from the above, real options as an individual industry of the financial science have taken up the matter with business and government agencies on the necessity to use capital market technologies in the real business environment, including also in the innovation theory (Trifonov, Yashin and Koshelev, 2014).

In respect to the development of a cluster innovation strategy, some options that are already known and practiced in business can be used with a view to improving the strategy under the condition of potential abandoning it in future. These opportunities enhance the flexibility of a strategic decision. It is required, however, to give an adequate valuation to them, primarily in terms of assessment of the cost of such adjusted strategy. In this case, it is regarded as a global investment project comprising an extensive portfolio of the cluster major specialized business lines characterizing core industries of the investing region enabling it to progress to new innovative opportunities of the development.

2 Model Setup

Let us stepwise consider the principles of generating the suggested model of cluster innovation strategy risk management using a real put option to abandon a strategy.
2.1 Real Put Option to Abandon a Strategy

When it comes to voluntary reasons for terminating projects, we have to do with a situation of exercising a real option to abandon a strategy (developing a business or a portfolio of different business lines).

The possibility to abandon a strategy or projects at one point of their implementation is called a real put option (Limitovskiy, 2011).

2.2 Entire Effect from a Project Taking into Account the Possibility to Terminate It and a Real Option

Limitovskiy (2011) suggests that the entire effect from a project should be determined taking into account the possibility to abandon a business (APV) by adding up its NPV and the real option value (Put), i.e.

\[
APV = NPV + Put = \sum_{t=0}^{n} \frac{CF_t}{(1 + i)^t} \prod_{r=0}^{t}(1 - p_r) + \sum_{t=1}^{n} \frac{L_t p_t}{(1 + r_f)^t} \prod_{r=0}^{t-1}(1 - p_r),
\]

where
- \( t \) – number of a year;
- \( n \) – planning horizon (the number of project years);
- \( CF_t \) – cash flow in the year \( t \) (RUB);
- \( i \) – rate of return having the same risk level as this project (%);
- \( p_t \) – probability of an unfavorable scenario (\( p_0 = 0 \));
- \( L_t \) – business disposal value in the year \( t \) (RUB);
- \( r_f \) – rate of risk-free return (%).

2.3 Entire Effect from an Innovation Strategy Taking into Account the Possibility to Terminate It and a Real Option

This strategy may be regarded as an investment project or a portfolio of projects. In this case, as a function that most adequately characterizes the present state and prospects for the development of individual companies and industries, it is possible to use a level of market capitalization by value (Cap).

As it was taken by us in the paper by Yashin, Trifonov and Koshelev (2017), we are going to analyze the following capitalization function:

\[
Cap = \alpha + \beta_1 \frac{P}{S} + \beta_2 \frac{EV}{EBITDA} = \alpha + \beta_1 \cdot PS + \beta_2 \cdot VE,
\]

where
- \( \alpha, \beta_1, \beta_2 \) – statistical constants;
- \( P \) – market price of one ordinary share (RUB);
- \( S \) – revenue per one ordinary share (RUB);
- \( EV \) – enterprise value (RUB);
- \( EBITDA \) – earnings before interest, taxes, depreciation, and amortization (RUB);
- \( PS \) – revenue multiplier;
- \( VE \) – earnings multiplier.
But as a project cash flow, we will use the incremental (differential) cash flow $\Delta CF_t$ (Brigham and Gapenski, 1993; Limitovskiy, 2011) representing a difference between the Cap values from time to time $t$.

Also, taking into consideration that the investing region may voluntarily abandon the strategy initially chosen by it at any time within the planning horizon, other than the last one, as well as on the presumption that in the event of implementation of the worst-case scenario, the probability of abandoning will be the same at any time, other than the last one, the expression for the region strategy APV may be recorded as follows

$$
APV = \sum_{t=0}^{n-1} \Delta CF_t \left( \frac{1 - p}{1 + i} \right)^t + \frac{\Delta CF_n}{(1 + i)^n} + \sum_{t=1}^{n-1} L_t p \left( \frac{1 - p}{1 + r_f} \right)^t.
$$

(3)

2.4 Estimate of Annual Average Probability of Abandoning a Strategy

It has been our belief up to now that the probability of terminating a strategy is known to us. If we have to do with the probability of voluntary abandoning a strategy, an optional variant may include the use of a formal procedure (Limitovskiy, 2011) whose essence in our case comes down to the following.

Let us suppose that the probability of abandoning the strategy is equal to the probability that the strategy rate of return will turn out to be less than the barrier minimum return level, i.e. the riskless rate $r_f$. That is why we are going to use it as a discount rate.

Then the annual average probability $p$ that the strategy will have to be terminated at this stage (in this year) may be determined according to the PERT approximate statistical estimate method (Limitovskiy, 2011). According to this method, the anticipated NPV value and its mean-square deviation are found using the formulas:

$$
E[\text{NPV}] = E[\text{NPV}_{\text{min}}] + 4 E[\text{NPV}_p] + E[\text{NPV}_{\text{max}}],
$$

(4)

$$
\sigma[\text{NPV}] = \frac{E[\text{NPV}_{\text{max}}] - E[\text{NPV}_{\text{min}}]}{6}.
$$

(5)

The normalized NPV value is defined as

$$
d = \frac{\text{NPV}_{\text{min}} - E[\text{NPV}]}{\sigma[\text{NPV}]}.
$$

(6)

The relevant probability $p$ may be found according to the area-under-normal-curve table as $N(d)$ (Brigham and Gapenski, 1993; Limitovskiy, 2011).

3 Empirical Results

In order to illustrate how the presented cluster innovation strategy risk management model operates using a real put option to abandon a strategy, let us consider the Nizhny Novgorod industrial innovation cluster for illustrative purposes.
Earlier in the paper by Yashin, Trifonov and Koshelev (2017), we obtained that the maximum synergistic effect for the Nizhny Novgorod industrial innovation cluster would be secured by purchasing an equivalent portfolio replicating the ‘Water Transport Activities’ industry represented by Volga Steamship Line (Volga Fleet). For that end, the investing region has to acquire the following portfolio that is more than adequate for it. The most promising business line in the Nizhny Novgorod cluster includes electric power transmission services, i.e. exactly what Inter-Regional High-Voltage Grid Company (IRHVGC) of the Central and Volga Regions carries on. This type of business needs to be replicated in the very near future approximately 89 times, i.e. it is required to increase the number of companies of this profile up to 89. The second position is held by the business operated by Vyksa Smelter (VMZ), i.e. pipe making for production and distribution of oil and gas, construction and housing and public utilities. Its share of participation (cooperation) in the cluster must be 0.141. At the same time, this portfolio requires two sales: 1) the type of business operated by LUKOIL, i.e. finding and producing oil and gas, producing oil-products and petrochemicals as well as marketing products made (companies of this profile to be sold 1.833 times relative to the value of this company assets); 2) the type of business operated by Volgogaz, i.e. installation and construction works, start-up and commissioning and repairs of gas supply facilities (to be sold 14 times). Since the equivalent portfolio is acquired, it is now also required to sell Volga Steamship Line (Volga Fleet) in whole to achieve the synergistic effect for the Nizhny Novgorod cluster amounting to 22,927,627 million USD.

Consequently, the innovation strategy of the Nizhny Novgorod cluster is hereafter regarded as a portfolio of 4 investment projects for the respective 4 titles, i.e. business lines represented by major core businesses of the region.

In order to predict the future dynamics of the Cap indicators of companies comparable in money terms according to the multiple regressions obtained in the paper by Yashin, Trifonov and Koshelev (2017) using the Statistica package (Khalafyan, 2007), proper allowance must be made for the non-linear nature of the change in the PS and VE parameters. It will irreversibly misrepresent the already identified historical dependencies. Thus, for instance, for LUKOIL PJSC, they have been obtained in the Mathematica package (Ruskeepaa, 2009; Dyakonov, 2010) using polynomials of various degrees (Figures 1 and 2). For the purposes of further forecast, the most adequate nature of the PS and VE parameters is attributed to polynomials of Degree 2, i.e. parabolas. We will use them in the most likely case.

In the paper by Yashin, Trifonov and Koshelev (2017), the optimal regional portfolio

\[(n_1, n_2, n_3, n_4) = (-1.832918, 0.141885, 89.187712, -14.056155),\]

making it possible to achieve the maximum synergistic effect includes LUKOIL’s share with a negative sign, i.e. this title in the mentioned share must be sold. Because of this, a degree 5 polynomial will be the worst-case scenario for the PS multiplier since in this case, the PS value will grow faster than other polynomials in the horizon period (Figure 1). But a degree 1 polynomial, i.e. a descending straight line, will be the best-case scenario for PS. By so doing, any opportunity cost or any imputed income respectively arising in the future in case of sale of LUKOIL PJSC is taken into
\begin{verbatim}
data := {{1, 1.08}, {2, 0.87}, {3, 0.26}, {4, 0.59}, {5, 0.47},
{6, 0.34}, {7, 0.4}, {8, 0.38}, {9, 0.23}, {10, 0.35}}
p1[x_] = Fit[data, {1, x}, x]
0.368667 - 0.0675758 x

g1 := Plot[p1[x], {x, 0, 11}]
p2[x_] = Fit[data, {1, x, x^2}, x]
1.19617 - 0.231326 x + 0.0148864 x^2

g2 := Plot[p2[x], {x, 0, 11}]
p5[x_] = Fit[data, {1, x, x^2, x^3, x^4, x^5}, x]
1.57867 - 0.477277 x - 0.0237442 x^2 + 0.0350122 x^3 - 0.0052583 x^4 + 0.000234615 x^5

g5 := Plot[p5[x], {x, 0, 11}]
gd := ListPlot[data, PlotStyle -> {PointSize[0.02]}]
Show[g1, g2, g5, gd, PlotRange -> {0, 1.5}]
\end{verbatim}

Figure 1: Polynomial Approximation of Historical Values of PS Multiplier for LUKOIL PJSC in the *Mathematica* Package
Figure 2: Polynomial Approximation of Historical Values of VE Multiplier for LUKOIL PJSC in the Mathematica Package
account. Such reasoning is true where the PS and VE multipliers are included into the Cap function with a positive sign.

The title shares included in an optimal portfolio with a positive sign should be purchased by the investing region. In this case, the choice of the worst-case and best-case scenarios will be to the contrary. With due consideration of this fact and with a view to predicting for subsequent years, we are going to use the following dependencies for titles included in the portfolio.

**LUKOIL** (sale):

\[
\text{Cap} = 330.3835 + 754.1247 \cdot \text{PS} + 24.338 \cdot \text{VE},
\]
\[
\text{PS}_{\text{pes}} = 1.57867 - 0.477277 t - 0.02377442 t^2 + 0.0350122 t^3 - 0.00525583 t^4 \\
+ 0.000234615 t^5,
\]
\[
\text{PS}_p = 1.19617 - 0.231326 t + 0.0148864 t^2,
\]
\[
\text{PS}_{\text{opt}} = 0.868667 - 0.0675758 t,
\]
\[
\text{VE}_{\text{pes}} = 11.7147 - 5.88042 t + 1.58525 t^2 - 0.178637 t^3 + 0.007476611 t^4 \\
- 0.0000294872 t^5,
\]
\[
\text{VE}_p = 7.33917 - 1.06367 t + 0.0822348 t^2,
\]
\[
\text{VE}_{\text{opt}} = 5.53 - 0.159091 t.
\]

**VMZ** (purchase):

\[
\text{Cap} = 287.4269 + 70.5602 \cdot \text{VE},
\]
\[
\text{VE}_{\text{pes}} = 4.00133 + 0.640303 t,
\]
\[
\text{VE}_p = 13.4463 - 4.08222 t + 0.429318 t^2,
\]
\[
\text{VE}_{\text{opt}} = 36.3333 - 46.0942 t + 21.5389 t^2 - 4.01476 t^3 + 0.306139 t^4 - 0.0075 t^5.
\]

**IRHVGC** (purchase):

\[
\text{Cap} = 620.8324 + 258.7387 \cdot \text{PS},
\]
\[
\text{PS}_{\text{pes}} = 2.184 - 0.258364 t,
\]
\[
\text{PS}_p = 3.54733 - 0.94003 t + 0.0619697 t^2,
\]
\[
\text{PS}_{\text{opt}} = 1.78733 + 2.76694 t - 2.17801 t^2 + 0.535666 t^3 - 0.0546638 t^4 + 0.00199487 t^5.
\]

**Volgogaz** (sale):

\[
\text{Cap} = 399.4141 + 136.5621 \cdot \text{PS},
\]
\[
\text{PS}_{\text{pes}} = 21.9627 - 13.99 t + 3.71587 t^2 - 0.43744 t^3 + 0.0195822 t^4 - 0.000103846 t^5,
\]
\[
\text{PS}_p = 12.5792 - 3.28619 t + 0.222386 t^2,
\]
\[
\text{PS}_{\text{opt}} = 7.68667 - 0.839939 t.
\]

Using the functions provided, it is possible to predict their values within the next 4 years for each company. The prediction is made for three scenarios: worst-case, most likely and best-case. In addition, all eventual results are multiplied by the respective
shares of titles comparable in money terms (Yashin, Trifonov and Koshelev, 2017) in the optimal portfolio of the investing region:

\[(n_1, n_2, n_3, n_4) = (-108.514501, 1.15111, 133.604342, -25.212066).\]

As the result, Table 1 shows the actual Cap values of the companies in 2015 and the predicted ones in 2016–2019 for the three scenarios. However, there is no data for 2019 in the worst-case scenario since in this case, the initially chosen strategy is not implemented to the end in this year. It is terminated in one of the three preceding years.

Table 1: Cap of Companies in Portfolio in 3 Scenarios (million USD)

<table>
<thead>
<tr>
<th>Issuer</th>
<th>2015</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Worst-case scenario</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LUKOIL</td>
<td>50,441</td>
<td>78,851</td>
<td>121,017</td>
<td>206,418</td>
<td>–</td>
</tr>
<tr>
<td>VMZ</td>
<td>3,378</td>
<td>1,228</td>
<td>1,280</td>
<td>1,332</td>
<td>–</td>
</tr>
<tr>
<td>IRHVGC</td>
<td>33,423</td>
<td>60,200</td>
<td>51,268</td>
<td>42,337</td>
<td>–</td>
</tr>
<tr>
<td>Volgogaz</td>
<td>10,027</td>
<td>28,796</td>
<td>56,509</td>
<td>105,610</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>Most likely scenario</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LUKOIL</td>
<td>50,441</td>
<td>87,670</td>
<td>98,945</td>
<td>113,090</td>
<td>130,106</td>
</tr>
<tr>
<td>VMZ</td>
<td>3,378</td>
<td>1,995</td>
<td>2,466</td>
<td>3,006</td>
<td>3,616</td>
</tr>
<tr>
<td>IRHVGC</td>
<td>33,423</td>
<td>107,328</td>
<td>124,104</td>
<td>145,163</td>
<td>170,507</td>
</tr>
<tr>
<td>Volgogaz</td>
<td>10,027</td>
<td>21,569</td>
<td>27,865</td>
<td>35,693</td>
<td>45,052</td>
</tr>
<tr>
<td></td>
<td>Best-case scenario</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LUKOIL</td>
<td>50,441</td>
<td>55,068</td>
<td>53,004</td>
<td>50,940</td>
<td>48,877</td>
</tr>
<tr>
<td>VMZ</td>
<td>3,378</td>
<td>5,704</td>
<td>10,821</td>
<td>17,850</td>
<td>26,573</td>
</tr>
<tr>
<td>IRHVGC</td>
<td>33,423</td>
<td>172,790</td>
<td>424,033</td>
<td>980,366</td>
<td>2,033,530</td>
</tr>
<tr>
<td>Volgogaz</td>
<td>10,027</td>
<td>4,724</td>
<td>1,832</td>
<td>-1,060</td>
<td>-3,952</td>
</tr>
</tbody>
</table>

Based on the data in Table 1, it is possible to calculate the incremental cash flows \(\Delta CF_t\) as a difference between the Cap values in neighboring years. The results are shown in Table 2. This table also contains present worths of the 2016–2019 incremental cash flows calculated in 2015 according to the riskless rate of 10.8% per annum as adjusted for Russia’s sovereign risk (Limitovskiy, 2011).

Having the information shown in Table 2, it is possible to use the PERT method (Limitovskiy, 2011) to estimate the annual average probability of abandoning the Nizhny Novgorod cluster innovation strategy developed in the paper by Yashin, Trifonov and Koshelev (2017), following which to calculate the entire effect from the strategy taking into account the possibility of its termination and the real option.

Using the data from Tables 1 and 2, let us estimate the NPV of each project, i.e. each industry represented by the relevant company, from the optimal portfolio of the investing region. In such a case, proper allowance should be made for any
opportunity cost or any imputed income arising in the future in case of selling the first and the fourth titles of the portfolio. And the NPV of each project should be estimated for each of the 3 scenarios.

Table 2: Incremental Cash Flows Cap of Companies in 3 Scenarios

<table>
<thead>
<tr>
<th>Issuer</th>
<th>PV&lt;sub&gt;2015&lt;/sub&gt;</th>
<th>2016</th>
<th>2017</th>
<th>2018</th>
<th>2019</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Worst-case scenario</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LUKOIL</td>
<td>116,651</td>
<td>28,410</td>
<td>42,167</td>
<td>85,401</td>
<td>–</td>
</tr>
<tr>
<td>VMZ</td>
<td>–1,860</td>
<td>–2,150</td>
<td>52</td>
<td>52</td>
<td>–</td>
</tr>
<tr>
<td>IRHVGC</td>
<td>10,326</td>
<td>26,776</td>
<td>–8,931</td>
<td>–8,931</td>
<td>–</td>
</tr>
<tr>
<td>Volgogaz</td>
<td>75,610</td>
<td>18,769</td>
<td>27,715</td>
<td>49,101</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>Most likely scenario</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LUKOIL</td>
<td>64,473</td>
<td>37,229</td>
<td>11,275</td>
<td>14,145</td>
<td>17,016</td>
</tr>
<tr>
<td>VMZ</td>
<td>–63</td>
<td>–1,383</td>
<td>470</td>
<td>540</td>
<td>610</td>
</tr>
<tr>
<td>IRHVGC</td>
<td>112,664</td>
<td>73,905</td>
<td>16,775</td>
<td>21,060</td>
<td>25,344</td>
</tr>
<tr>
<td>Volgogaz</td>
<td>27,509</td>
<td>11,542</td>
<td>6,296</td>
<td>7,828</td>
<td>9,359</td>
</tr>
<tr>
<td></td>
<td>Best-case scenario</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LUKOIL</td>
<td>–391</td>
<td>4,627</td>
<td>–2,064</td>
<td>–2,064</td>
<td>–2,064</td>
</tr>
<tr>
<td>VMZ</td>
<td>17,222</td>
<td>2,326</td>
<td>5,117</td>
<td>7,029</td>
<td>8,723</td>
</tr>
<tr>
<td>IRHVGC</td>
<td>1,438,201</td>
<td>139,367</td>
<td>251,242</td>
<td>556,333</td>
<td>1,053,165</td>
</tr>
<tr>
<td>Volgogaz</td>
<td>–11,187</td>
<td>–5,303</td>
<td>–2,892</td>
<td>–2,892</td>
<td>–2,892</td>
</tr>
</tbody>
</table>

1. Worst-case scenario:

\[
\begin{align*}
\text{NPV}^{(1)} &= 50,440.796 - 116,650.948 = -66,210.152, \\
\text{NPV}^{(2)} &= -3,378.342 - 1,860.2 = -5,238.542, \\
\text{NPV}^{(3)} &= -33,423.13 + 10,325.6 = -23,097.53, \\
\text{NPV}^{(4)} &= 10,027.368 - 75,610.064 = -65,582.696, \\
\text{NPV}_\Sigma &= -160,128.92.
\end{align*}
\]

2. Most likely scenario:

\[
\begin{align*}
\text{NPV}^{(1)} &= 50,440.796 - 64,473.402 = -14,032.606, \\
\text{NPV}^{(2)} &= -3,378.342 - 63.413 = -3,441.755, \\
\text{NPV}^{(3)} &= -33,423.13 + 112,663.703 = 79,240.573, \\
\text{NPV}^{(4)} &= 10,027.368 - 27,509.434 = -17,482.066, \\
\text{NPV}_\Sigma &= 44,284.146.
\end{align*}
\]
3. Best-case scenario:

\[ NPV^{(1)} = 50,440.796 + 391.282 = 50,832.078, \]
\[ NPV^{(2)} = -3,378.342 + 17,222.456 = 13,844.114, \]
\[ NPV^{(3)} = -33,423.13 + 1,438,200.842 = 1,404,777.712, \]
\[ NPV^{(4)} = 10,027.368 + 11,186.666 = 21,214.034, \]
\[ NPV_{\Sigma} = 1,490,667.938. \]

Making use of the formulas (4)–(6) and \( NPV_{\text{min}} = 303.945 \) million USD to cover the sale of Volga Fleet (Yashin, Trifonov and Koshelev, 2017), let us assess the probability of abandoning the strategy:

\[
E[\text{NPV}] = \frac{-160,128.92 + 4 \cdot 44,284.146 + 1,490,667.938}{6} = 251,279.267,
\]
\[
\sigma[\text{NPV}] = \frac{1,490,667.938 + 160,128.92}{6} = 275,132.81,
\]
\[ d = \frac{303.945 - 251,279.267}{275,132.81} \approx -0.91, \]
\[ N(d) = 0.5 - 0.3186 = 0.1814, \quad \text{i.e.} \quad p = 18.14\%. \]

Now it is possible to calculate the NPV of the project portfolio using the first portion of the formula (3):

\[
\text{NPV} = \sum_{t=0}^{n-1} \Delta CF_t \left( \frac{1 - p}{1 + i} \right)^t + \frac{\Delta CF_n}{(1 + i)^n}. \tag{7}
\]

However, for each individual company, its incremental cash flows \( \Delta CF_t \) must be discounted at a rate corresponding to the respective economic sector. Since \( \Delta CF_t \) characterizes a variation in the company market capitalization by value (Cap), the company equity cost of capital should be used as a discount rate. It may be calculated using the well-known CAPM model (Brigham and Gapenski, 1993; Kruschwitz, 1999; Damodaran, 2002; Ogier, Rugman and Spicer, 2004; Roche, 2005; Limitovskiy, 2011):

\[
k_s = k_{RF} + MRP \cdot \beta, \tag{8}
\]

where \( k_s \) – cost of company equity capital (%);
\( k_{RF} \) – risk-free return (%);
\( MRP \) – market risk premium (%);
\( \beta \) – factor characterizing the volatility of return on equity of a specific company relative to the average yield in the securities market.

Following the recommendations provided by Limitovsky (2008), let us take 4.21% as a risk-free return in US dollars, and let us take 13.35% as a market premium for the risk of investment in shares of Russian corporations. The coefficients \( \beta \) for the industries ‘Oil and Natural Gas Industry’, ‘Metallurgical Industry’, ‘Power Industry’ and ‘Housing Development Sector’ will be 0.67, 0.88, 0.81 and 0.92 respectively.
Then let us determine the equity cost of capital for each of the 4 titles of the optimal portfolio of the investing region.

**LUKOIL:**

\[ k_s = 4.21\% + 13.35\% \cdot 0.67 = 13.1545\%. \]

**VMZ:**

\[ k_s = 4.21\% + 13.35\% \cdot 0.88 = 15.958\%. \]

**IRHVGC:**

\[ k_s = 4.21\% + 13.35\% \cdot 0.81 = 15.0235\%. \]

**Volgogaz:**

\[ k_s = 4.21\% + 13.35\% \cdot 0.92 = 16.492\%. \]

Knowing the discount rates and the annual average probability of abandoning the strategy, the formula (7) may be used to calculate the NPV of each project of the optimal portfolio of the investing region.

**LUKOIL:**

\[
\begin{align*}
1 - p &= 1 - 0.1814 \frac{1}{1.131545} = 0.723436, \\
\text{NPV}^{(1)} &= 50,440.796 - 37,229.155 \cdot 0.723436 - 11,274.656 \cdot 0.723436^2 \\
&\quad - 14,145.299 \cdot 0.723436^3 - \frac{17,016.159}{1.131545^4} = 1,872.084.
\end{align*}
\]

**VMZ:**

\[
\begin{align*}
1 - p &= 1 - 0.1814 \frac{1}{1.15958} = 0.705945, \\
\text{NPV}^{(2)} &= -3,378.342 - 1,383.266 \cdot 0.705945 + 470.45 \cdot 0.705945^2 \\
&\quad + 540.191 \cdot 0.705945^3 + \frac{609.931}{1.15958^4} = -3,593.005.
\end{align*}
\]

**IRHVGC:**

\[
\begin{align*}
1 - p &= 1 - 0.1814 \frac{1}{1.150235} = 0.711681, \\
\text{NPV}^{(3)} &= -33,423.13 + 73,905.246 \cdot 0.711681 + 16,775.228 \cdot 0.711681^2 \\
&\quad + 21,059.518 \cdot 0.711681^3 + \frac{25,344.075}{1.150235} = 49,740.128.
\end{align*}
\]

**Volgogaz:**

\[
\begin{align*}
1 - p &= 1 - 0.1814 \frac{1}{1.16492} = 0.702709, \\
\text{NPV}^{(4)} &= 10,027.368 - 11,541.706 \cdot 0.702709 - 6,296.209 \cdot 0.702709^2 \\
&\quad - 7,827.54 \cdot 0.702709^3 - \frac{9,358.92}{1.16492^4} = -8,990.376.
\end{align*}
\]
In total, the project portfolio NPV will be \( \text{NPV}_\Sigma = 39,028.831 \text{ million USD} \).

Let us then calculate the value of the real put option to abandon the strategy using the second portion of the formula (3):

\[
\text{Put} = \sum_{t=1}^{n-1} L_t p \left( \frac{1 - p}{1 + r_f} \right)^t.
\] (9)

Using the data from Table 1 for the worst-case scenario, we will obtain the following disposal values of the investing region portfolio in 2016–2018:

\[
L_1 = 1,227.936 + 60,199.578 = 61,427.514, \\
L_2 = 1,279.942 + 51,268.395 = 52,548.337, \\
L_3 = 1,331.949 + 42,337.078 = 43,669.027.
\]

Then by using the formula (9), it is possible to calculate the value of the real put option to abandon the strategy.

\[
\frac{1 - p}{1 + r_f} = \frac{1 - 0.1814}{1.108} = 0.738809,
\]

\[
\text{Put} = 61,427.514 \cdot 0.738809 + 52,548.337 \cdot 0.738809^2 + 43,669.027 \cdot 0.738809^3 = 19,541.304.
\]

The entire effect from the Nizhny Novgorod cluster innovation strategy taking into account the possibility to terminate it and the real option will be

\[
\text{APV} = \text{NPV}_\Sigma + \text{Put} = 39,028.831 + 19,541.304 = 58,570.135.
\]

Dividing this value and \( \text{NPV}_{\text{min}} = 303.945 \text{ million USD} \) by the correcting factor \( k_i = 1.045489 \) for Volga Fleet (Yashin, Trifonov and Koshelev, 2007), we will obtain that

\[
\text{APV} = 56,021.761 > 290.72 = \text{NPV}_{\text{min}}.
\]

And this is indicative of the profitability of the Nizhny Novgorod cluster innovation strategy chosen by the investing region.

## 4 Conclusion

Finally, let us formulate the following practical conclusions.

1. Under the current conditions of higher economic risks in Russia as a developing market, it is relevant to consider the opportunities of adjusting the cluster strategy that has already been initiated and even, subject to the relevant threats of the region economic environment, of abandoning it and switching to another strategy.
2. It makes sense to investigate a cluster development innovation strategy set in the form of an optimal portfolio of major companies representing the respective regional economic sectors for any possibility to abandon its implementation at any time within the planning horizon, other than the last year.

3. In order to manage the risks of the industrial innovation cluster evolution, this article employed a real put option technology to abandon the strategy. As a function that most adequately characterizes the present state and prospects for the development of individual companies and industries, it is possible to use a level of market capitalization by value. And as a cash flow of industrial projects, it is possible to use an incremental cash flow representing a difference between the market capitalization values from time to time.

4. The entire effect from the Nizhny Novgorod cluster innovation strategy taking into account the possibility to terminate it and the real option was 56,021.761 million USD, which was much greater than the minimum required value 290.72 million USD due to the sale of the Volga Steamship Line (Volga Fleet). It should be noted that the entire effect from the strategy consists of the project portfolio NPV as much as 39,028.831 : 1.045489 = 37,330.695 million USD and the value of the real put option to abandon the strategy as much as 19,541.304 : 1.045489 = 18,691.066 million USD. Consequently, the option to abandon the strategy significantly enhances its entire effect.

5. This cluster evolution risk management philosophy utilizing the real option techniques eventually allows to adjust the global regional strategy when required.

These results may be useful to state administration bodies, for instance, during developing a future strategy of innovative development of the Nizhny Novgorod Region.

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