Using a Compound Real Option to Develop an Innovation Strategy for an Industrial Cluster

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Abstract. The purpose of this paper is to apply such a technology to develop an innovation strategy for the pilot clusters defined by the state, which would allow to make flexible management decisions. The proposed method for this involves the use of a compound real option, which includes the following components to be applied in the following order: 1) an option to reduce and exit the cluster strategy, 2) an option to develop and replicate the experience in the cluster, 3) an option to change over and temporarily stop the cluster strategy, and 4) an option to delay the start of the new cluster strategy. Combining a compound real option exactly as presented avoids unreasonable managerial decisions to withdraw from the current cluster strategy, which would include multiple tactical cluster development opportunities that have already been implemented. In other words, a put option is first added to the evaluation of the current strategy. This is an option to reduce and exit the cluster strategy. And then if the current strategy continues, the next three call options are added to it.

1 Introduction

In the context of import substitution policy, the holistic development of major innovation systems of the country becomes relevant. In this regard, the development of a value-oriented evolution strategy for the region innovation system is based on the analysis of the prospects and socio-economic value of innovational and industrial clusters in the region. To do this, it is necessary to align the values of the clusters with the value system of the region. For this purpose, those regional and republican clusters, which have the necessary innovation potential, i.e. there are enough production, financial, labor and other resources for successful development, are analyzed in detail [6].

Allocating pilot clusters that are most useful to the population of the region, based on the traditions and historical areas of production, is an important and at the same time challenging task for the executive authorities of the region. It is also necessary to apply such technologies to develop an innovation strategy for the pilot clusters defined by the state, which would allow to make flexible management decisions. Given the wide range of opportunities and threats to such economic formations, compound real options could be such technologies.

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Although the components of a compound real option can be quite varied, let us consider the most common types.

Abandonment option (an option to abandon a project). During the life of a project, a company can choose to terminate the project without investing anything else in it. This choice is called a default option. Some default options are accompanied by an opportunity to obtain a salvage value from the project. This option type is usually called an abandonment option [2].

Growth option (an option to develop and replicate the experience). One of the most common types of options is a growth option, sometimes called an expansion option. When a company has a growth option, it has the ability to invest additional funds and expand the scale of the project at a date later in the project life [2].

Changeover option. If prices or demand changes, the company management can plan a changeover (e.g., in the commodity composition of a facility – "product flexibility"). Alternatively, materials and end products can be produced by different production processes ("process flexibility") [5].

A changeover often refers to a technology. For example, one technology may be more cost-effective in high-demand conditions, another may be more cost-effective in low-demand conditions [1].

Option to temporarily terminate the production process (a temporary termination option). If operations are less profitable than expected, the production process control may temporarily stop and then start up again [5].

Option to delay a project. Many projects do not require the company to initiate them today. In other words, either the initial investment is made today, and the project begins to generate value, or the initial investment is deferred to a later date and, if it is done, then when the project begins to generate value. While many projects require the company to develop quickly, significant value can be gained by waiting for some uncertainty to be resolved. While such waiting may enable competitors to gain an advantage, it can reveal valuable information about the nature of the market [2].

With regard to strategizing the innovational and industrial cluster development, we will apply a compound option having components similar to those listed above for projects. The use of such components allows, in our opinion, to obtain sufficient flexibility in the management of the cluster development strategy.

2 Materials and Methods

Our proposed method involves the use of a compound real option including the following components, which should be applied in the following order:

1. Option to reduce and exit the cluster strategy.
2. Option to develop and replicate the experience in the cluster.
3. Option to change over and temporarily stop the cluster strategy.
4. Option to delay the start of the new cluster strategy.

Combining the compound real option in exactly this order makes it possible to avoid unreasonable managerial decisions to withdraw from the current cluster strategy, which would include multiple tactical cluster development opportunities that have already been implemented. In other words, a put option is first added to the evaluation of the current strategy. This is an option to reduce and exit the cluster strategy. And then if the current strategy continues, the next three call options are added to it.

We will evaluate the effect of the innovational and industrial cluster development strategy using the compound real option method according to the following algorithm.

1. Calculating the expected value of future cash flows from the current cluster strategy, given at the time of evaluation:

$$\mathrm{E}[S_0] = \frac{S_{1,\mathrm{opt}} \cdot p_{\mathrm{opt}} + S_{1,\mathrm{pes}} \cdot p_{\mathrm{pes}}}{1 + \mathrm{WACC}}, \quad (1)$$

where $S_{1,\mathrm{opt}}$ and $S_{1,\mathrm{pes}}$ - optimistic and pessimistic values of future cash receipts from the project adjusted to their initial conditions (RUB);

p_{opt} and p_{pes} - probabilities of the best-case and worst-case project development scenarios;

WACC - weighed average capital cost of the cluster core company (%).

2. Calculating the net present income $\mathrm{NPV}_{\mathrm{old}}$ of the base-case cluster strategy scenario, i.e. without options or with options already in place:

$$\mathrm{NPV}_{\mathrm{old}} = \mathrm{E}[S_0] - K, \quad (2)$$

where K - investment in the strategy implementation, i.e. the total discounted value of the cluster core company capital stock (RUB).

3. Calculating the expected value of future cash flows from the cluster strategy for a new option on strategy without options or a strategy with options already in place.

4. Calculating the $\mathrm{NPV}_{\mathrm{new}}$ of the new cluster strategy scenario.

5. Calculating a premium for a call (ΔC_0) or put (ΔP_0) option:

$$\Delta C_0 = \mathrm{NPV}_{\mathrm{new}} - \mathrm{NPV}_{\mathrm{old}} \text{ or } \Delta P_0 = \mathrm{NPV}_{\mathrm{new}} - \mathrm{NPV}_{\mathrm{old}}. \quad (3)$$

This algorithm is repeated several times, until all the possibilities of the cluster development strategy with appropriate real options are taken into account.

Evaluating some components of a compound real option on a cluster strategy requires a special approach. This applies to the option to reduce and exit the strategy and the option to delay the start of the new strategy. To do this, let us look at them in more detail.

Option to reduce and exit the cluster strategy. In the worst-case scenario, the value $S_{1,\mathrm{pes}}$ under the condition of constant probability p_{pes} in time is calculated as per the formula that was obtained in [7]:

$$\mathrm{APV} = \mathrm{PV} + P = \sum_{t=1}^{n-1} \mathrm{CF}_t \left(\frac{1 - p_{\mathrm{pes}}}{1 + \mathrm{WACC}} \right)^t + \frac{\mathrm{CF}_n}{(1 + \mathrm{WACC})^t} + \sum_{t=1}^{n-1} L_t p_{\mathrm{pes}} \left(\frac{1 - p_{\mathrm{pes}}}{1 + r_f} \right)^t, \quad (4)$$

where APV - adjusted present value of future cash flows of the cluster strategy in the worst-case scenario, taking into account the possibility of withdrawal from the strategy (RUB);

PV - present value of future cash flows of the cluster strategy in the worst-case scenario (RUB);

P - value of the put option to exit the cluster strategy (RUB);

CF_t - cash flow of the strategy in the worst-case scenario in the year t (RUB);

n - planning horizon (number of years);

L_t - disposal value in the year t, i.e. the anticipated total discounted value of the cluster core company capital stock (RUB);

r_f - rate of risk-free return (%).

Option to delay the start of the new cluster strategy. Here, a possibility for the cluster core company to change over to a new technology is considered as a new strategy. The value of this “live”, i.e. outstanding call option in the year t can be calculated by the formula [3, 4]:

$$C_t^N = \frac{1}{1 + r_f} \left(pC_{t+1,u} + (1 - p) C_{t+1,d} \right), \quad (5)$$

where the pseudoprobability p is calculated as

$$p = \frac{r_f - r_d}{r_u - r_d};\tag{6}$$

r_u - yearly growth rate of cash flows from the new technology in the best-case scenario (%);

r_d - yearly growth rate of cash flows from the old technology in the worst-case scenario (%);

$C_{t+1,u}$ - option value in case of its growth in the next year $t+1$ (RUB);

$C_{t+1,d}$ - option value in case of its reduction in the next year $t+1$ (RUB).

The value of a "dead", i.e. exercised call option in the year *t* can be calculated as

$$C_t^A = \max\{S_t - K_t, 0\},\tag{7}$$

where S_t - cash flows from the new or old technology in the year *t* (RUB);

K_t - option exercise value, i.e. the cluster core company management services in the year *t* (RUB).

Since the value K_t is anticipated for the years *t* based on IFRS data in the year prior to year 0, this call option turns out to be an Asian option, i.e. an option with a variable strike price.

3 Results

As an example of implementing the presented method, let us consider the process of developing a growth strategy for the pilot power industry cluster in the Nizhny Novgorod region. Paper [6] has demonstrated that it is more profitable for the Nizhny Novgorod innovational and industrial cluster to develop the power sector. For this purpose, the Nizhny Novgorod region has the necessary innovation potential, i.e. sufficient production, financial, labor and other resources for the successful evolution of the cluster.

This pilot cluster is represented by the cluster core company – TNS Energo NN PJSC. The cash flow (CF) arranged by the years of this company is shown in Table 1. At the time of valuation, i.e. in 2019, the weighted average cost of its capital is $\text{WACC} = 12.56\%$, the total discounted value of the capital stock is $K = 2,233,864$ thousand rubles, the risk-free rate of return is $r_f = 4.21\%$ (*www.old.conomy.ru*).

Table 1. Yearly cash flow of TNS Energo NN PJSC (RUB, in thousands).

	2013	2014	2015	2016	2017	2018	2019
CF	498,625	- 441,563	567,721	2,931,398	-4,313,838	3,282,929	330,600

Using the *WolframAlpha* internet service (*www.wolframalpha.com*), let us approximate the dependence of the company's cash flows on time. From the economic point of view, the dependencies represented by the parabola and the logarithm are the most adequate, so we take them as equally likely best-case and worst-case scenarios. Then we can forecast cash flows for the next 5 years according to the two selected dependencies (Table 2).

Let us evaluate the profitability of the base-case pilot cluster strategy scenario, i.e. without options. The discounted anticipated cash flows for 2020 at the rate of $\text{WACC} = 12.56\%$ will be:

- in the best-case scenario: $S_{1,\text{opt}}$ = 8,770,806 thousand rubles,
- in the worst-case scenario: $S_{1,\text{pes}}$ = 2,358,870 thousand rubles.

Table 2. Cash flow forecast for 2 equally likely scenarios for TNS Energo NN PJSC (RUB, in thousands).

Scenario	2020	2021	2022	2023	2024
Best-case (parabola)	1,225,461	1,691,155	2,243,985	2,883,931	3,610,993
Worst-case (logarithm)	556,786	577,128	595,326	611,787	626,815

Then according to formulas (1) and (2), we obtain that

$$\mathrm{E}[S_0] = \frac{8,770,806 \cdot 0.5 + 2,358,870 \cdot 0.5}{1.1256} = 4,943,886 \text{ (thousand rubles)},$$

$$\mathrm{NPV} = 4,943,886 - 2,233,864 = 2,710,022 \text{ (thousand rubles)},$$

i.e. the strategy is profitable. But it does not take into account the likely possibilities for further development of the cluster. For that end, let us supplement its analysis with the corresponding components of the compound real option.

1. *Option to reduce and exit the cluster strategy.* If the worst-case scenario occurs, the disposal value in the year *t*, i.e. the anticipated total discounted value of the cluster core company capital stock (L_t) can be calculated by increasing the value of $K = 2,233,864$ thousand rubles at the rate of $\mathrm{WACC} = 12.56\%$ each and every year. In this respect, the last year 2024 is not taken into account because at this point, the core company has no time to abandon the current cluster strategy. The results of L_t calculations are presented in Table 3.

Table 3. Disposal value of TNS Energo NN PJSC in worst-case scenario (RUB, in thousands).

	2020	2021	2022	2023	2024
L_t	2,514,437	2,830,251	3,185,730	3,585,858	-

The pilot cluster strategy is then evaluated with the put option on possible exit from it using formulas (4), (1) and (2):

$$\mathrm{APV} = 556,786 + 577,128 \cdot \frac{1-0.5}{1.1256} + 595,326 \cdot \left(\frac{1-0.5}{1.1256}\right)^2 + 611,787 \cdot \left(\frac{1-0.5}{1.1256}\right)^3 + \frac{626,815}{1.1256^4} +$$

$$+2,514,437 + 2,830,251 \cdot \frac{1-0.5}{1.0421} + 3,185,730 \cdot \left(\frac{1-0.5}{1.0421}\right)^2 + 3,585,858 \cdot \left(\frac{1-0.5}{1.0421}\right)^3 =$$

$$= 1,374,728 + 5,001,847 = 6,376,575 \text{ (thousand rubles)},$$

$$\mathrm{E}[S_0] = \frac{8,770,806 \cdot 0.5 + 6,376,575 \cdot 0.5}{1.1256} = 6,728,581 \text{ (thousand rubles)},$$

$$\mathrm{NPV} = 6,728,581 - 2,233,864 = 4,494,717 \text{ (thousand rubles)}.$$

In other words, owing to the put option to exit the strategy, it has become even more profitable. The premium for this option according to formula (3) will be

$$\Delta P_0 = 4,494,717 - 2,710,022 = 1,784,695 \text{ (thousand rubles)}.$$

2. *Option to develop and replicate the experience in the cluster.* Short-term investments in 2020 will amount to 551,486 thousand rubles, and in the best-case scenario they will increase the cash flow (CF) by 13.5% due to the reduction of losses by grid companies

(*www.old.conomy.ru*). Then the option to develop the experience in the cluster will provide even more value to the cluster strategy:

$S_{1,\mathrm{opt}} = 1,225,461 + (8,770,806 - 1,225,461)1.135 - 551,486 = 9,237,942$ (thousand rubles),

$$\mathrm{E}[S_0] = \frac{9,237,942 \cdot 0.5 + 6,376,575 \cdot 0.5}{1.1256} = 6,936,086 \text{ (thousand rubles)},$$

$$\mathrm{NPV} = 6,936,086 - 2,233,864 = 4,702,222 \text{ (thousand rubles)},$$

where the premium for this call option according to formula (3) will be

$$\Delta C_0 = 4,702,222 - 4,494,717 = 207,505 \text{ (thousand rubles)}.$$

3. *Option to change over and temporarily stop the cluster strategy.* Under the worst-case scenario, it is assumed for TNS Energo NN PJSC to change over to a new technology of TNS Energo Rostov-on-Don PJSC. The cash flow (CF) arranged by the years for TNS Energo Rostov-on-Don PJSC is shown in Table 4 (*www.old.conomy.ru*).

Table 4. Yearly cash flow of TNS Energo Rostov-on-Don PJSC (RUB, in thousands).

	2013	2014	2015	2016	2017	2018	2019
CF	- 803,122	1,029,575	- 808,148	1,193,714	254,101	1,104,088	766,859

At the time of valuation, i.e. in 2019, the weighted average cost of capital of TNS Energo Rostov-on-Don PJSC is $\mathrm{WACC} = 12.62\%$. The incremental total discounted share price at the time of the possible decision to change over to the new technology in 2020, according to Conomy of M3 (*www.old.conomy.ru*), will be

$$\Delta K = K_{\mathrm{Rostov}} - K_{\mathrm{NN}} = 6,708,617 - 2,540,079 = 4,168,538 \text{ (thousand rubles)}.$$

Using the *WolframAlpha* internet service (*www.wolframalpha.com*), let us approximate the dependence of the cash flows of TNS Energo Rostov-on-Don PJSC on time. The most optimistic scenario includes the dependence of the cash flows of this company on time, expressed by a polynomial of degree 3. It can be used to forecast optimistic cash flows for the next 5 years (Table 5).

Table 5. Cash Flow Forecast for Best-Case Scenario of TNS Energo Rostov-on-Don PJSC (RUB, in thousands).

Scenario	2020	2021	2022	2023	2024
Best-case (polynomial of degree 3)	1,199,583	1,707,962	2,498,930	3,644,690	5,217,445

The anticipated cash flows of TNS Energo Rostov-on-Don PJSC discounted in 2020 at the rate of $\mathrm{WACC} = 12.62\%$ will be $S_{1,\mathrm{opt}}$ = 10,481,385 thousand rubles in the best-case scenario. Then for TNS Energo NN PJSC, they will be

$$S_{1,\mathrm{pes}} = 556,786 + 10,481,385 - 4,168,538 = 6,869,633 \text{ (thousand rubles)}$$

As a result, using formulas (1) and (2) for TNS Energo NN PJSC, we obtain that

$$\mathrm{E}[S_0] = \frac{9,237,942 \cdot 0.5 + 6,869,633 \cdot 0.5}{1.1256} = 7,155,106 \text{ (thousand rubles)},$$

$$\mathrm{NPV} = 7,155,106 - 2,233,864 = 4,921,242 \text{ (thousand rubles)}.$$

In other words, owing to the call option to change over to the new technology, the cluster strategy has become even more profitable. The premium for this option according to formula (3) will be

$$\Delta C_0 = 4,921,242 - 4,702,222 = 219,020 \text{ (thousand rubles).}$$

4. *Option to delay the start of the new cluster strategy.* The possibility to change over to the new technology of TNS Energo Rostov-on-Don PJSC always exists for TNS Energo NN PJSC throughout the entire planning horizon up to 2024. In this regard, it is necessary to determine the best time to change over to the new technology. To do this, it is necessary to compare the prices of the “live” option and the “dead” option in each node of the binomial tree of the option to delay.

First, we bring together the anticipated cash flows of the old and new technologies taking into account that we take the worst-case scenario for TNS Energo NN PJSC and the best-case scenario for TNS Energo Rostov-on-Don PJSC. In this case, the average value for the 2 technologies is taken as the starting point $t = 0$. Also, in the internal nodes of the binomial tree, the obtained values are averaged.

Then on the basis of the data in Tables 5 and 2, the annual rates r_u and r_d respectively are calculated for the new and old technologies, which are then inserted into formula (6) for each forecast year to calculate the pseudoprobabilities p and $1-p$ (Table 6).

Table 6. Calculation of pseudoprobabilities of 2 technologies.

	2021	2022	2023	2024
r_u	0.423796	0.463106	0.4585	0.43152
r_d	0.036535	0.031532	0.02765	0.024564
p	0.01437	0.024487	0.033538	0.043091
$1 - p$	0.98563	0.975513	0.966462	0.956909

The option in question is Asian, so it is required to calculate its strike price for each of the 5 forecast years. For TNS Energo NN PJSC, the IFRS management services in 2019 amounted to 373,265 thousand rubles. This will be the strike price of the option to delay in 2019. The option strike price incremental rate K_t is $\text{WACC} = 12.56\%$ for TNS Energo NN PJSC. Using this rate, we can calculate the strike price of this option.

After that, starting from the last year and gradually passing to the 1st forecast year, in each node of the option binomial tree, the prices of the “live” option and the “dead” option are calculated using formulas (5) and (7), and the one, which is more expensive, is chosen.

As a result, the “dead” option is more expensive in $t = 0$, i.e. for TNS Energo NN PJSC, this means that $C_1 = 458,038$ thousand rubles. Therefore, it is more profitable to exercise it immediately, i.e. in 2020.

Given this option to delay, we obtain that the value of the pilot cluster strategy will become even greater:

$$S_{1,\text{opt}} = 9,237,942 + 458,038 = 9,695,980 \text{ (thousand rubles),}$$

$$\mathrm{E}[S_0] = \frac{9,695,980 \cdot 0.5 + 6,869,633 \cdot 0.5}{1.1256} = 7,358,570 \text{ (thousand rubles),}$$

$$\text{NPV} = 7,358,570 - 2,233,864 = 5,124,706 \text{ (thousand rubles).}$$

And the premium for the call option in question will be

$$\Delta C_0 = 5{,}124{,}706 - 4{,}921{,}242 = 203{,}464 \text{ (thousand rubles).}$$

4 Discussion

The final conclusion for the pilot power industry cluster strategy will be that using the method of compound real options has made it possible to increase the value of the strategy from $\text{NPV} = 2{,}710{,}022$ thousand rubles to 5,124,706 thousand rubles.

The obtained results can be useful to public authorities in the processes of planning the development of innovational and industrial clusters and harmonious development of the country's territories.

5 Conclusion

Finally, let us formulate the most important theoretical and practical conclusions:

1. It is necessary to apply such technologies to develop an innovation strategy for the pilot clusters defined by the state, which would allow to make flexible management decisions. Given the wide range of opportunities and threats to such economic formations, compound real options could be such technologies.
2. The method proposed in this paper involves the use of a compound real option, which includes the following components to be applied in the following order: 1) an option to reduce and exit the cluster strategy, 2) an option to develop and replicate the experience in the cluster, 3) an option to change over and temporarily stop the cluster strategy, and 4) an option to delay the start of the new cluster strategy.
3. As an example of implementing the presented method, we consider the process of developing a growth strategy for the pilot power industry cluster in the Nizhny Novgorod region, which is represented by the core company – TNS Energo NN PJSC. Using the method of compound real options allowed to increase the value of the strategy for this cluster from $\text{NPV} = 2{,}710{,}022$ thousand rubles to 5,124,706 thousand rubles.

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