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STRATEGIC VALUE OF MINERAL ASSETS – SELECTED METHODOLOGICAL ASPECTS

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Purpose: The article, both in the part of the considerations about strategic value and real options and in the conclusions from the conducted research, aims to demonstrate the validity of recognizing strategic value. The postulated validity is not only the result of the ambition to increase the complexity of the calculations but clearly, an attempt to justify the hypothesis that understanding almost every investment project through the real option category, or a portfolio of such options is a natural way of thinking about value factors.
Design/methodology/approach: The article analyzes real options to calculate profitability and considers strategic value as an economic category resulting from decision flexibility. The valuation of real options, which is often used in the mining industry and raw material projects, is still an alternative to the so-called traditional methods. However, the development of the calculation possibilities and the methodological apparatus in modern management enhanced this widespread approach and is considered more accurate and comprehensive. The example discussed in this paper explores the option value of delaying the exploration of a copper deposit by two years, given the project's sensitivity to raw material contract prices.
Findings: The calculation results indicate that the static NPV simplifies the problem of profitability testing, which may be justified in some circumstances. Only in some circumstances will this not result in a wrong investment decision. An additional and important aspect of the article is to draw attention to the issue of the option premium as, on the one hand, a determinant of profitability, and on the other hand, the characteristics of the phenomenon of optionality as a necessary condition for its occurrence.
Originality/value: The article considers the nature of the value category using the example of calculating the so-called "strategic value" of an investment project. Most scientific works in a similar area are limited to the issue of the applicability of the analyzed methods and their practical effects. Meanwhile, this article draws attention to the consequences of such a practice regarding the ontology of the value category.
Keywords: strategic value, real options, raw material project, financial efficiency.
Category of the paper: Research paper.

1. Introduction

Estimating various forms of value is the domain of finance and financial science, but the results of this process radiate out to all economic activities. In this regard, it is a vital issue of universal significance. At the same time, this is a methodologically difficult and ambiguous problem. In this article, the value category is identified through the following research area:

1. It is about estimating the value of mineral assets.
2. This involves a concise and consistent method for estimating the so-called strategic value.

To that effect, the recognition of strategic value, understood here as the asset valuation process in terms of the so-called option value, is the subject of this study. This issue has also been discussed in many scientific publications at the intersection of geology and its economics and finance, along with a pure investment approach, which was the starting point for this content. The geological problem, the main focus of which is the identification of minerals and their deposits, together with the technical aspects of identification, extraction, and any necessary processing, appears to pose a challenge for rationalism not only in the respect that the exploited deposit and the organized excavation must be characterized. The second path of rationalism is the issue of the enterprise's liabilities and rationality that stems from economic rationalism.

Within the presented framework, a geological problem becomes an economic or, more narrowly, financial problem. Determining such a logical implication is conventional, or rather only intuitive or convenient, due to the deduction in the analysis of problems whose conclusions concern financial issues. This article adopts an opposite approach to the problem. Investments, in their substance and common denominator, are about increasing the value of available assets. A mining project is one possible circumstance for such a process. The investment dilemma arises not from how to conduct a specific mining process but how to increase the value of assets by “passing” them through the organizational scheme of a real process, which, among many others, is a mining project.

The aims of the article are limited to cognitive theory in the area of value categories. Considering the number of existing studies, which, as a result of introducing a large amount of data and additional assumptions into the considerations, are supposed to give the impression of accuracy, in the author's opinion, they cause disruption in conclusions. Each seemingly accurate and complex calculation that is not complete (not being the evaluator's work that accurately and completely characterizes a raw material project with unique features) carries the risk of error when trying to relate the results to constituted or constituted theories. Naturally, such works can serve as a kind of inspiration, but their analysis requires above-average criticality. Additionally, this work is not a contribution to the real options methodology, but an assessment of this calculus in terms of the consistency of the understanding of the category of "value" with this methodological approach.

2. A mineral deposit as a subject of valuation – from a geological to an economic problem

Since the primary subject of the analysis is strategic value, namely, taking into account the equivalent value of embedded options, it is necessary to answer the question: To what extent do the methodological implications of the options account correspond to the approach to the value category for the investor? Additionally, if the said degree of correspondence was not uniquely quantifiable, it would be cognitively valuable to characterize at least the valuation process itself as an attempt to synthesize a geological problem and an economic one.

Mineral deposits are regarded as mineral assets for two reasons. First of all, it formally results from the classification of these natural resources into the mineral assets group in the POLVAL *The Polish Code for the Valuation of Mineral Assets* (POLVAL, 2021), which so provides, additionally based on other existing valuation standards for the raw material economy of countries or organizations dealing with the matter in question. Second, due to the economic premise that an in situ mineral can be traded, it is therefore subject to a valuation process – in this article, the emphasis of the valuation is placed on the investment economics of such assets.

The process of investor valuation as the search for value in contemporary finance is, in fact, a broad approach to economic potential, measurable using a formal and methodologically advanced toolkit. Therefore, despite the existence of relatively traditional approaches to determining the value of assets, including (Saługa, 2009):

- market,
- revenue,
- cost

science and practice show a certain lack of methods while dealing with the ontology of the "value" category. The most common aspects include insufficient consideration of uncertainty and failure to explore flexibility in decision-making during the process itself (Yang et al., 2022; Majd & Pindyck, 1987). A clear-cut example of the significance of decision-making flexibility is provided by research in the area of zinc and lead mining in Poland (Dzieża et al., 2002; Pera, 2010).

Research into the applicability of individual approaches and their respective methods indicates that traditional approaches are more common, and methodologically advanced ones are less popular (Saługa, 2009). This does not necessarily indicate that calculating the value of real options, considered a modern approach, is in any way overrated/overstated. However, it has significant scientific value, as indicated by former studies on the option value for mineral projects (McDonald, Siegel, 1986; Dixit, Pindyck, 1994; Paddock et al., 1988). In more recent scientific literature, from the years 1995-2015, where the analysis of real options for the mineral industry is considered, one can find Savolainen's position on the issue (cf. Savolainen, 2016) and Slade's particular consideration of the copper mine (cf. Slade, 2001). In turn, an analysis of 1,500 entities from Norway, Denmark, and Sweden, in terms of knowledge and scope of application of the real options account, indicated that only 6% of them use this option, especially in the energy, biotechnology, research and development sectors (Horn et al., 2015). The specific nature of mineral industry served as a field for generalizations to the options account for valuation purposes, and the developing methodological approaches can be sensibly tested in the field of these investments. Moreover, raw materials management is a narrowing of the issue of natural resources management in general, for which real options methods seem to be appropriate, as analyzed by Brennan and Schwartz (cf. Brennan, Schwartz, 1985).

In the literature, the genesis of this concept is indicated in the 1977 work by Myers, who rather than inventing it, pointed out and named a phenomenon that is actually common. The author called on an example of outside capital suppliers securing loan-specific assets, but when assessing the borrower's potential to repay the obligation, they consider the entity in terms of its option value (Myers, 1977). What exactly is a real option was not and is not an easy question to answer, and, therefore, this issue is difficult to parameterize. Rudny, after Micalizzi and Trigeorgis, pointed out four aspects that explain the category of a real option (Rudny, 2009), i.e.:

- valuation model,
- decision-making process,
- a way of thinking,
- organizational model.

The usefulness of real options as a valuation model clearly indicates that the value for the investor does not result only from the value of estimated revenue and, therefore, will not be solely the result of calculating discounted cash flows. When conducting a valuation using an option model, the investor states that they are ready to pay and hold the investment in exchange for more than the cash flows estimated in one scenario. Not because the analysis of cash flows and their present value (at least at a specific point in time *0* on the relative timeline) are unreliable or because there is some classified information, but because decision flexibility (if any) is taken into account. This means that one invests in future benefits, considering managerial rationality for a given investment. This expression reflects the components of the strategic value of the project (Pera, 2010):

$$\boldsymbol{SV = NPV + ROV_e + E_{syn}} \tag{1}$$

where:

SV – strategic value of the project,

ROV_e – cash equivalent of the flexibility of options included in the project,

E_{syn} – cash equivalent of the synergism effect (if there are more options "built-in" to the project).

The most basic and probably the most frequently described option will be considered here – the delay option (postponement/option to wait/deferred payment). Based on theoretical assumptions, this option is relatively easy to understand, as it means the possibility of refraining from starting an investment project. Based on the logic of options in general, the determinant of its implementation is properly identified and calculated for future profitability.

In the literature, this option may be called an investment option. This approach was used by Saługa, who mentioned this term as an alternative when characterizing the option (cf. Saługa, 2011). In turn, Mizerka characterized the delay and investment options separately, though as interrelated, further pointing to the studies by McDonald and Siegel, which dealt with the valuation of investment and delay options, and Dixit and Pindyck, who examined the valuation of investment options (Mizerka, 2005). Further, Mizerka stated that "the value of the delay option (...) can be determined as the difference between the value of the investment option and the classic NPV (...)". Going back to the formula written earlier, one could conclude about the substantial identity between the project strategic value and the investment option value (narrowing the problem to a state in which one option is considered, not their portfolio, which allows us to omit the effect of synergism).

Given the above, it could be considered that the delay option is the possibility of postponing investment implementation, but in the sense of deferring exactly the procedure that would affect the formation of the NPV. Therefore, if a plan for subsequent cash flows were to be implemented, but covering different periods on the time axis, we could talk about an option and understand this valuation as searching for value in terms of time optimization, as defined in the mentioned work by McDonald and Siegel. The delay option would be a way to answer a very natural question in economics: "WHEN, knowing WHAT and HOW to invest, IF?" Thus, the answer to "when" results from the assessed time optimization, but "in what" and "how" are not questions in this case – they are more of an inspiration for the specific "what" and "how", which are characterized financially through "classic" NPV. Ultimately, "if" draws attention to the risk factor, as at least one value factor is allowed to change, and it is for this reason that the use of an option account rationalizes the approach to value estimation. It can be assumed that the inclination of an investor or capital manager to analyze decision flexibility should be proportional to the recognition degree of the sources of investment uncertainty, and then to the best possible estimated risk.

Is the investment option then a potential specific to a given investment project or more of an economic potential in general? Based on the distinction between the delay option and the investment option, this distinction should be finally identified. While the delay option is the possibility of implementing the project with a temporary delay, the investment option is the possibility of undertaking the investment at all. The delay option concerns a recognized but postponed stream of cash flows, while the investment option concerns a different, potential stream. What these options have in common is the coincidence of waiting for a possible "better," more profitable moment. This phenomenon will be expressed by the classic relationship between investment profitability and the value of cash flows, expressed in the figure below.

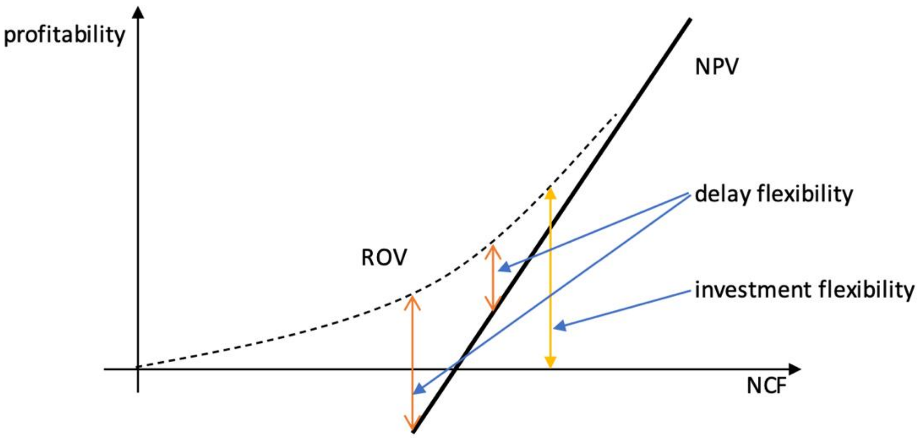

Figure 1. Strategic value of the project.

Source: own study.

The literature characterizing real options almost always recommends considering the concept of options from the point of view of financial options, as within the meaning of this article. Among these most important areas of similarities and differences, there is a catalog of variables which, on the one hand, indicates the existence of options (and for real options, the appropriate expression would be the occurrence of the phenomenon of option potential), and, on the other hand, directly indicates the determinants of the option value – the variables are listed in Table 1.

Table 1.
Parameters of financial and real options

Option parameter equivalents	
financial option	**real option**
current price of underlying asset S	present value of the CF project
exercise price of option X	investment outlay N
price volatility of underlying asset σ	volatility of cash flows σ'
option expiration date T	project implementation date T'
risk-free rate r_f	risk-free-rate r_f

Source: Pera, 2010.

The phenomenon category may be an apt name for the problem because it generalizes both the financial instrument (i.e., option) and the right to manage the investment process as part of exercising decision-making flexibility. When trying to address the outlined problem of the delay option and the investment option in terms of the description of the phenomenon, it would be necessary to specify the cause of the phenomenon.

Among those dealing with this issue, real options are considered a more complex and difficult issue than financial options. As Cortazar, Grvet, and Urzua pointed out, real options pose a greater methodological challenge due to the investment time perspective and complexity, as they are often a problem compared to a portfolio of American options, the valuation of which is complicated (Cortazar et al., 2008).

For the financial option, the cause of the phenomenon is purely speculation. Recognizing derivatives as a risk management tool and a stabilizing potential for the investor, we are only talking about one side of the contract. The intention to protect against the volatility of rates, indexes, or macroeconomic indicators is natural but has no connection with the risk management process until another party voluntarily appears in the contract and is willing to bet to the contrary. The financial option, as a realized economic phenomenon, is then dealt with (assuming the fulfillment of formal conditions) after concluding a contract between two parties with homogeneous interests but heterogeneous expectations. The first step with financial consequences for the option writer and buyer is to receive and pay the option premium, respectively.

Real options do not typically have a set option premium (as its price) because it is not a characteristic of this type of option. However, the premium can be viewed as a factor of real options. Investment options and delay options can be summarized by analyzing this premium. When considering whether and when to start an investment project, there is no binding question or requirement for capital. This process resembles analyzing real options, which are different from non-binding speculations. Real options can only be exercised by those with decision-making flexibility, who can decide to act now or later, or not at all. This suggests the existence of an option premium for real options, but it is different from the premium of a financial option.

The option premium could be considered these expenses that lead the investor to actual decision-making on project management. Typically, the costs of organizing the project, if any, or the opportunity costs of refraining from alternative investments in which the possible delay would not be implemented. For exploration investments, this will be the proportion of the delay time to the concession time with the concession cost and similar fees. However, the payoff function for the other party will be different than in the case of financial options. The benefits from the existence of an option, or rather the right to make a decision, are distributed among all stakeholders contributing to the fact that the investor has the right to make a decision. In turn, the issue of risk is included in a certain systemic understanding of the problem. A concession seller or an investor implementing an alternative investment project is deprived of the right exercised by the entity exercising its delay or investment option.

The option premium understood in this way will not affect the gross value of the project, but when analyzing profitability, it will reduce it. In turn, to recognize this phenomenon, the option premium will identify the economic phenomenon as a real option.

3. Calculation of the strategic value with the delay option – an example of copper deposit exploration

Considering the nature and consequences of the phenomenon of real options, this part of the article will analyze a hypothetical mineral project in a copper deposit, the value of which is to be determined considering decision-making flexibility – namely, by calculating the strategic value with the possibility of delaying the start of the project.

The inference process will be deployed through:

1. Identifying the underlying instrument and the causes of its volatility.
2. Making assumptions about the calculation method.
3. Calculating the strategic value of the project.
4. Comparing results as premises for an investment decision and analysis of possible discrepancies in conclusions.

Before considering the example, it is worth determining the degree of relation between the planned exemplification resulting from theoretical assumptions and the practice of mineral project management. The presented example is flawed with arbitrary assumptions and a lack of comprehensiveness – as it turns out, the perceived limitation is a certain property of considerations in this field. As Guj and Chandra pointed out (2019), studies into mineral project management in the field of ROV analysis are very often carried out using not very realistic examples and simplifications. The researchers in the cited work conducted, as they say, an analysis of a mineral project implemented by a copper mine, but the theoretical conclusions confirm the common hypothesis about the validity of ROV analysis in the mining industry. Additionally, to assess the methodology application, the results of their research indicate a greater information potential for the analysis of real options compared to traditional discount methods. It can, therefore, be assumed that using simplified examples is a kind of work ergonomics strategy and has the disadvantage that scientific work will not always provide instructions for the company manager. However, it must be considered that an analysis of a scientific nature is not a direct instruction; it would then be shallow; it is more an inspiration for multiple recommendations of a relatively universal nature. Then, it fulfills its role and expectations in science.

Step 1

In the method of real options, which constitute hypothetical states of nature, the underlying instrument will be the project value with the assumption that it will be subject to appropriately probable fluctuations due to the volatility of the sales price of the output at market prices. To calculate the said volatility, the standard deviation of the rates of return on the prices of three-month raw material futures contracts was calculated[1]; the analysis of raw material contract prices is also adopted in other studies (cf. Xiao et al., 2020). The conclusion on the significance of the impact of raw material price volatility on the value of the project itself can be found in the work by Haque, Topal, and Lilford (Haque et al., 2014). Based on contract price levels expressed in USD/Mg, and using *London Metal Exchange* quotations, the dynamics of annual price changes were calculated, assuming continuous capitalization in the years 2012-2022[2]:

$$\boldsymbol{R_{ln} = \ln\left(\frac{P_N}{P_0}\right)} \tag{2}$$

$$R_{ln} = \ln\left(\frac{8\,400.00}{7\,930.00}\right) = 5.76\%$$

where:

R_{ln} –rate of return/relative change in raw material prices over the entire period,

P_N –price per megagram of raw material at the end of the last *N* year – of the summer period,

P_0 – price per megagram of raw material at the end of the last year before the first N year – of the summer period.

The average value

$$\boldsymbol{\bar{R}_{\ln} = \frac{1}{N} R_{ln}} \tag{3}$$

$$\bar{R}_{\ln} = \frac{1}{10} \cdot 5.76\% = 0.58\%$$

average value is used to estimate the standard deviation of the sample returns

$$\boldsymbol{\sigma = \sqrt{\frac{1}{N-1}\sum_{t=1}^{N}(R_{ln_t} - \bar{R}_{\ln})^2}} \tag{4}$$

$$\sigma = \sqrt{\frac{1}{10-1}\sum_{t=1}^{10}(R_{ln_t} - 0.58\%)^2} = 20.18\, p.p.,$$

where:

R_{ln_t} –annual rate of return/relative change in raw material prices in *t*-th years as

[1] In the example, the analysis of the risk parameter is limited to one factor of the project gross value, and the authors point out that methodological correctness/accuracy imposes the obligation to use the so-called consolidated project volatility, i.e., all value factors; however, the issue of the sensitivity of strategic value to the risk assessment method is not dealt with in this work.

[2] The period covered by the data was selected arbitrarily to avoid the possible need to introduce weights distinguishing the significance of price volatility from earlier and less distant periods from the moment of analysis.

$$R_{ln_t} = \ln(P_t) - \ln(P_{t-1}), \text{ a } t = 1, 2, \dots, N. \quad (5)$$

The use of the LCFR approach (*logarithmic stock price returns approach*) results from the approval of this method anchored in the literature (Mun, 2006) and is justified in this case by the absence of negative raw material prices.

Step 2

Given the property that $\sigma_S = \sigma_{NCF}$, gdy when $NCF = S + CF^-$, whereas $CF^- = const.$, denoting:

σ_S – standard deviation from sales revenue,

σ_{NCF} – standard deviation from net cash flows,

CF^- – value of negative cash flows

coefficients of increase or decrease in the value of cash flows will be determined after one period – in the example considered, one year. In line with a binomial tree idea, these coefficients will have the following forms and values:

$$u = e^{\sigma\sqrt{\Delta t}}, \quad (6)$$

$$d = e^{-\sigma\sqrt{\Delta t}}, \quad (7)$$

because $ud = 1$.

Given the project variability implied by the price volatility of the extracted raw material, the following can be calculated:

$$u = e^{0.2018} = 1.22,$$

$$d = e^{-0.2018} = 0.82.$$

Assuming that the investment project in the copper deposit is characterized as follows: the estimated net value of the NPV is at the level of $CU\ -4$, which leads either to reject or to consider changing the decision regarding its launch date. Analysis of excavated material prices, i.e., the project value factor, may indicate the potential of the planned investment project. Therefore, the strategic value will be estimated from a two-year perspective, bearing in mind that expenses would be incurred during these two years – in the first year $I_1 = CU30\ m$, and in the second year $I_2 = CU\ 20\ m$. The present values of these expenses, using the risk-free rate r_f at the level of 5% to discount them, are:

$$PV(I_1) = CU30\ m \cdot e^{-0.05} = CU28.54\ m$$

$$PV(I_2) = CU20\ m\ \cdot e^{2\cdot(-0.05)} = CU18.10\ m$$

$$\sum_{i=1}^{2} PV(I_i) = CU46.64\ m$$

Therefore, the gross value of the project $PV = CU - 4\ m + CU46.64\ m = CU42.64\ m$ po after one year can be two states of nature in the binomial option value model:

$$PV_u = PVu = CU42.64\ m \cdot 1.22 = CU52.17\ m$$

in the event of an increase in the copper price after one year from time t_o, and

$$PV_d = PVd = CU42.64\,m \cdot 0.82 = CU34.84\,m$$

in the event of a decline in the copper price after one year from time t_o. Whereas, the three possible states of nature for the adopted assumptions after two years are:

$$PV_{uu} = PVu^2 = CU63.83\,m,$$
$$PV_{ud} = PVud = CU42.64\,m,$$
$$PV_{dd} = PVd^2 = CU28.47\,m.$$

Step 3

The investor's basic decision-making criterion is profitability. The net present value of the investment project underpins a specific and professional approach to it, which in the circumstances of the option phenomenon is the state of nature identified based on appropriate premises. In the example analyzed, three states of nature can be distinguished, based on the assumptions made, which affect the determination of the option value.

First, if the value of the project, thanks to the delay in the decision to start it, would increase to the value of PV_{uu}, the so-called project payoff would be:

$$ROV_{uu} = \max(PV_{uu} - I, 0), \tag{8}$$

and if it fell to the value PV_{dd}:

$$ROV_{dd} = \max(PV_{dd} - I, 0). \tag{9}$$

A change that results in one increase and one decrease, resulting in the value of PV_{ud}, determines ROV_{ud}:

$$ROV_{ud} = \max(PV_{ud} - I, 0). \tag{10}$$

Therefore, the net project value in the event of a maximum increase in the raw material price, within the limits of the volatility examined, would be:

$$ROV_{uu} = \max(CU63.83\,m - CU46.64\,m; 0) = CU17.19\,m$$

In turn, in the opposite case, the calculation of the net project value is:

$$ROV_{dd} = \max(CU28.47\,m - CU46.64\,m; 0) = CU0$$

Finally, after one increase and one decrease:

$$ROV_{ud} = \max(CU46.64\,m - CU46.64\,m; 0) = CU$$

The option valuation, or rather the strategic valuation, of the project in the assumed and considered approach, is a specific combination of option values with appropriate parameterization by the probability *p*. This parameter is a probability of the form:

$$\boldsymbol{p} = \frac{e^{r_f} - d}{u - d}, \tag{11}$$

that corrects and limits the impact of extreme values in such a way (form for a shift by one period) that:

$$\boldsymbol{ROV_0} = \frac{p(ROV_u) + (1-p)ROV_d}{e^{r_f \Delta t}}. \tag{12}$$

Therefore, it is the sum of the project value at the limits of its specified volatility, discounted at the risk-free rate, and weighted by probability. In the example, the probability p has the value:

$$p = \frac{e^{0.05} - 0.82}{1.22 - 0.82} = 0.5759.$$

The strategic project value is calculated as:

$$ROV_0 = \frac{0.5759^2 \cdot CU17.19\,m + 0.4241^2 \cdot CU0 + 0.5759 \cdot 0.4241 \cdot CU0}{e^{2 \cdot 0.05}} = CU5.16\,m$$

In turn, the option value OP_0 as the difference between the strategic value and the net present value without decision flexibility, namely:

$$\boldsymbol{OP_0 = ROV_0 - NPV}, \quad (13)$$

would be the result of the difference:

$$OP_0 = CU5.16\,m - (CU - 4\,m) = CU9.16\,m$$

The graphical presentation of a two-period binomial tree is presented in Figures 2 and 3.

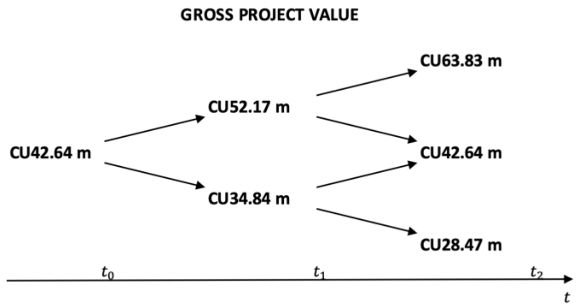

Figure 2. Project Gross Value.

Source: own study.

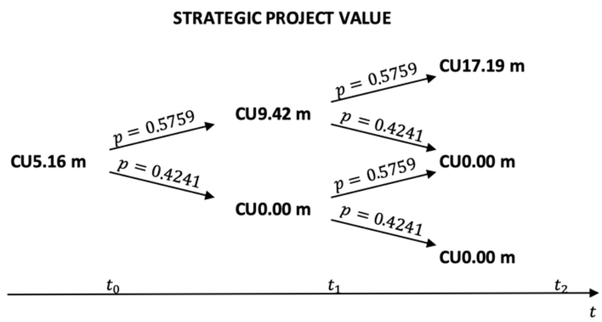

Figure 3. Project Strategic Value.

Source: own study.

Step 4

First, the interpretation of the results indicates that the change in the decision criterion resulted in a different nature of the decision. While, based on the NPV criterion, the project was ineffective, generating revenues of CU 4 m lower than their expected level, the strategic value criterion leads to the decision to implement the investment, as the expected revenues in current values will be CU 5.16 m higher than expected. Naturally, the use of the revenue category here results from the assumption that the project's variability results from sales, which will be associated with positive cash flows. However, considering optionality is critical to the effectiveness of the project's two-fold analytical approach. Second, referring to the question answered by the delay option, it should be stated that the investment in the copper deposit and its exploration within the planned and assessed organizational scope, assuming market absorption at market prices, should be started with a two-year delay, which will increase the profitability of the investment, which will exceed its threshold level by CU 5.16 m. Therefore, formally:

$$If: t_2 \rightarrow t_0 \Longrightarrow NPV_{t=0} < 0 \rightarrow NPV_{t=2} > 0 \Longleftrightarrow ROV_0 \equiv NPV_{t=2}e^{-2r_f}.$$

By contrast, the phenomenon of optionality, or more precisely, temporal optionality, is characterized by:

$$NPV_{t=0} \overset{\Delta t}{\rightarrow} ROV_0 \wedge NPV_{t=0} \neq ROV_0.$$

The above formulas are not general statements but are specific to the conclusions drawn from the analysis of the mineral investment case.

4. Conclusions and discussion

Decision flexibility as a phenomenon can be described as outlined in Figure 4.

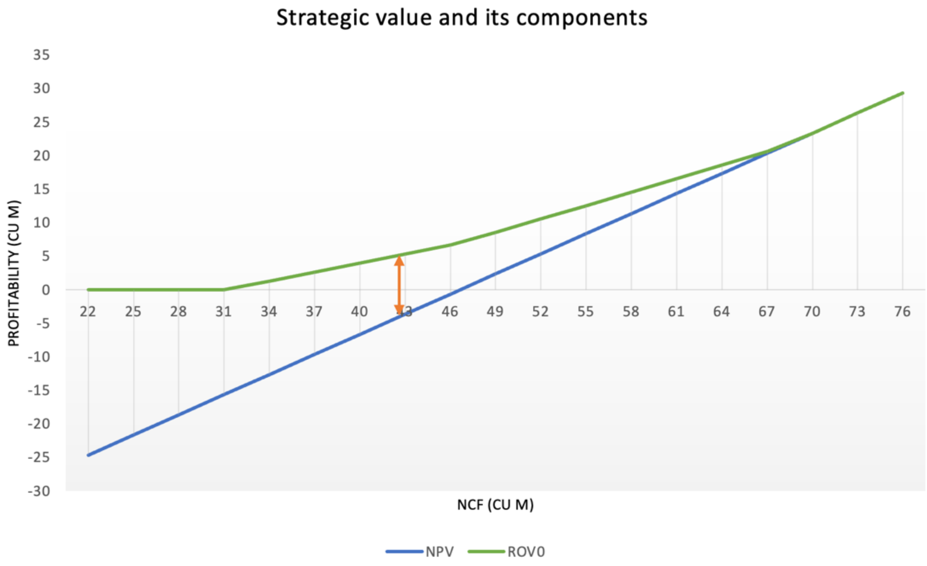

Figure 4. Strategic value of the project – the delay option considered.

Source: own study.

The distance marked with an arrow in Figure 4 corresponds to the option value of CU 9.16 m and the marked place characterizes the mineral project based on the undertaken assumptions. This indicates the existence of decision-making flexibility, which, when computed into the profitability calculation, increases the value of the decision criterion. Both values are affected by the sales value, which in turn is influenced by the price of the raw material. As the sales value increases, these values become more similar to each other, indicating that the decision-making criterion based on the strategic value becomes less significant. Naturally, this conclusion is part of the attributes of the options account, and it aligns with the findings of other studies (cf. Cortazar, Cassasus, 1998; Dimitrakopoulos, Abdel Sabour, 2007).

Referring, in turn, to the theoretical assumptions presented in the earlier part of the article, the indicated distances (arrows) in Figure 5 characterize the scale of the investment option phenomenon.

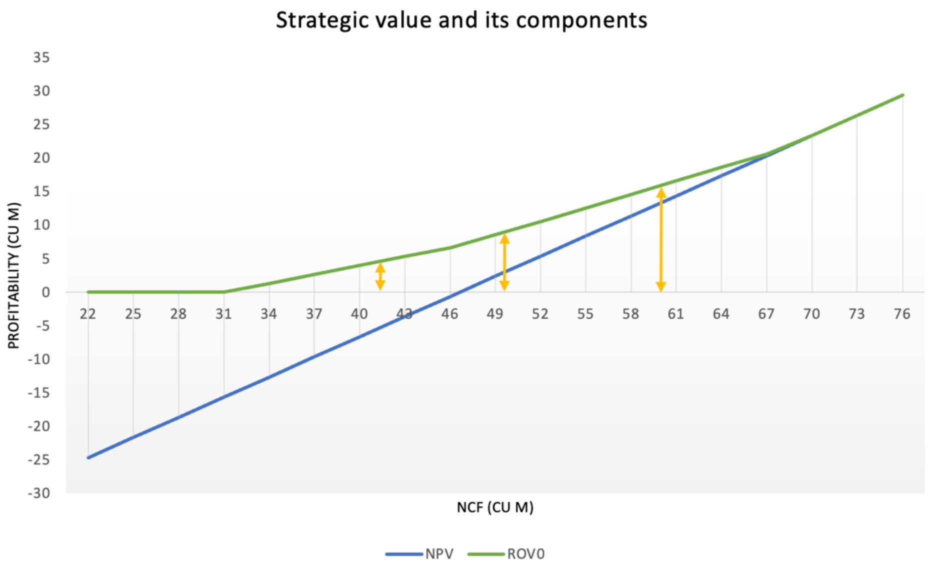

Figure 5. Project Strategic Value – investigating investment options.

Source: own study.

The distinction between the delay and investment options postulated in the article indicates the different nature of these two, with the necessary reservation that such a distinction is cognitively and theoretically important. In the example under consideration, the value of the investment option should be recognized at the level of CU 5.16 m, but a clear interpretation that the valuation of the investment option reaches a specific value does not seem to be general enough. The distinction between the investment option and the delay option is the issue of any decisions already made regarding the start of the investment.

While a fairly common motive for determining the value of the delay option is the legitimate concern not to reject a project that is potentially profitable, and not necessarily at the moment of valuation in terms of an immediate launch, the investment option does not necessarily have to be dictated by this reason. Since such a specific reference point is not assumed, the value of the investment option remains a specific function – in the case of the example in this article, the function of the market price of the raw material, and in the general case of all risky variables of the project value. In Figure 5, each arrow is the correct interpretation of the value of an investment option.

Planned further research in the indicated area should concern the issue raised in the earlier part of the article – namely, the profitability of the project with the recognition of the option premium equivalent understood under the nomenclature of financial options, i.e., the identification of the price or set of expenses that ensure the existence and availability of real options for a specific option and an investment option. Undoubtedly, an important limitation of the article in its comprehensive conclusions, but also many works referred to in the content, is treating the raw materials economy as a financial database. As noted in the first part of the article, raw material investments were used to make generalizations in the field of finance. Additionally, it was assumed that the raw material project is the subject of the capital transformation dilemma, but it is worth noting that the postulated comprehensiveness of strategic value factors should take into account the issues of technical circumstances. Attention is drawn to this in the work of Marmer and Slade, where the consideration of real options is enriched with the characteristics of the copper mine in terms of location, technology, geology, and geochemistry (Marmer, Slade, 2018).

References

1. Brennan, M.J.. Schwartz, E.S. (1985). Evaluating Natural Resource Investments. *The Journal of Business Vol. 58(2)*, pp. 135-157.
2. Cortazar, G., Cassasus, J. (1998). Optimal timing of a mine expansion: Implementing a real options model. *The Quarterly Review of Economics and Finance Vol. 38(3), Part 2*, pp. 755-769.
3. Cortazar, G., Schwartz, E.S., Cassasus, J. (2003). Optimal exploration investments under price and geological—technical uncertainty: a real options model. In: D.A. Paxson (Ed.), *Real R & D Options* (pp. 149-165). Oxford: Butterworth-Heinemann.
4. Cortazar, G., Gravet, M., Urzua, J. (2008). The valuation of multidimensional American real options using the LSM simulation method. *Computers & Operations Research, Vol. 35(1)*, pp. 113-129.
5. Dimitrakopoulos, R.G., Abdel Sabour, S.A. (2007). Evaluating mine plans under uncertainty: Can the real options make a difference? *Resources Policy, Vol. 32(3)*, pp. 116-125.
6. Dixit, A., Pindyck, R. (1994). *Investment under Uncertainty*. Hoboken: Princeton University Press.
7. Dzieża, J.A., Kicki, J., Saługa, P. (2002). Real options in mine project budgeting – Polish mining industry example. *Risk Analysis, III.* WIT Press, pp. 27-36.
8. Guj, P., Chandra, A. (2019). Comparing different real option valuation approaches as applied to a copper mine. *Resources Policy, Vol. 61*, pp. 180-189.

9. Haque, M.A., Topal, E., Lilford, E. (2014). A numerical study for a mining project using real options valuation under commodity price uncertainty. *Resources Policy, Vol. 39(C),* pp. 115-123.
10. Horn, A., Kjærland, F., Molnár, P., Steen, B.W. 2015. The use of real option theory in Scandinavia's largest companies. *International Review of Financial Analysis, Vol. 41*, pp. 73-81.
11. Majd, S., Pindyck, R.S. (1987). Time to build, option value, and investment decisions, *Journal of Financial Economics, Vol. 18(1),* pp. 7-27.
12. Marmer, V., Slade, M.E. (2018). Investment and uncertainty with time to build: Evidence from entry into U.S. copper mining. *Journal of Economic Dynamics and Control, Vol. 95*, pp. 233-254.
13. McDonald, R., Siegel, D. (1986). The Value of Waiting to Invest. *The Quarterly Journal of Economics Vol. 101(4)*, pp. 707-728.
14. Mizerka, J. (2005). *Real options in the financial assessment of investment effectiveness (Opcje rzeczywiste w finansowej ocenie efektywności inwestycji).* Poznań: Wydawnictwo AE w Poznaniu.
15. Mun, J. (2006). *Real Options Analysis: Tools and Techniques for Valuing Strategic Investment and Decisions.* Hoboken: Wiley.
16. Myers, S.C. (1977). Determinants of corporate borrowing. *Journal of Financial Economics Vol. 5(2),* pp. 147-175.
17. Paddock, J.L., Siegel, D.R., Smith J.L. (1988). Option Valuation of Claims on Real Assets: The Case of Offshore Petroleum Leases. *The Quarterly Journal of Economics, Vol. 103*, pp. 479-508.
18. Pera, K. (2010). *Integrated assessment of the financial efficiency of a raw material investment project* (*Zintegrowana ocena efektywności finansowej surowcowego projektu inwestycyjnego).* Katowice: Wydawnictwo AE w Katowicach.
19. POLVAL (2021). *Kodeks wyceny aktywów geologiczno-górniczych*. Kraków: Polskie Stowarzyszenie Wyceny Złóż Kopalin.
20. Rudny, W. (2009). *Real options in the process of creating enterprise value (Opcje rzeczowe w procesie tworzenia wartości przedsiębiorstwa).* Katowice: Wydawnictwo AE w Katowicach.
21. Saługa, P. (2009). *Economic evaluation of projects and risk analysis in mining (Ocena ekonomiczna projektów i analiza ryzyka w górnictwie).* Kraków: IGSMiE PAN.
22. Saługa, P. (2011). *Decision-making flexibility in the valuation processes of geological and mining projects (Elastyczność decyzyjna w procesach wyceny projektów geologiczno-górniczych)*. Kraków: IGSMiE PAN.
23. Savolainen, J. (2016). Real options in metal mining project valuation: Review of literature. *Resources Policy, Vol. 50*, pp. 49-65.

24. Slade, M.E. (2001). Valuing Managerial Flexibility: An Application of Real-Option Theory to Mining Investments. *Journal of Environmental Economics and Management, Vol. 41(2)*, pp. 193-233.
25. Xiao, C., Florescu, I., Zhou, J. (2020). A Comparison of Pricing Models for Mineral Rights: Copper Mine in China. *Resources Policy, Vol. 65*.
26. Yang, W., Fang, N., Wang, Y., Long, T., Deng, S., Xue, M., Deng, B. (2022). Value evaluation of mining right based on fuzzy real options. *Resources Policy, Vol. 78*.