ASSESSMENT OF THE OPTIMUM PARTICIPATION LEVEL IN MINING PROJECTS: RISKS AND UNCERTAINTIES

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Abstract

By and large, mining projects involve uncertainties and risks, and also require huge investments, which can consume the entire budget of a company. In this context, creating partnerships can make these projects execution easier. In this study the optimal level of participation of a granite mining project was assessed. The project presents the risk of financial losses due to uncertainties related to the initial investment, the selling price and cost of mineral production. The uncertainties were measured through Monte Carlo simulation to get the project risk. In such case, the optimal level of participation in the project is determined by maximizing the utility function. The obtained results show that the creation of partnerships can help the project accomplishment and may not require all the company’s budget and consequently allowing for new investments.

Keywords:
Mining projects; uncertainties; risks; partnerships; financial participation level.

1. INTRODUCTION

The Brazilian extractive mining industry is of great importance. After all, it accounted for 4.0% of GDP in 2014, which amounted to US $80.2 billions. Add to this that 23.7% of the Brazilian exports in that year were primary mineral goods, justifying the heavy investments in sector (1). To get a more accurate picture and confirmation of these reported statements, the Brazilian Institute of Mining states that in 2018 about US$ 53 billion will be invested in the mineral industry (2).

The need for high investments is amongst the most important particularities of mining projects, which can consume the entire budget of a company. In addition, there are uncertainties in relation to production costs and selling price of mineral commodities, which imply risks of financial losses. In order to minimize them, (3) recommend the formation of partnerships (joint ventures) with other companies. Thus, the cash flow of each partner will be proportional to their level of participation in the project (4). Other formulations can be found in (5, 6, 7, 8, 9, 10).
Considering the risks and uncertainties, the challenge is to estimate what should be the optimum level participation in these projects. (11) points out that the adoption of economic valuation models based on Discounted Cash Flow (DCF) is not recommended in these circumstances because it does not capture the uncertainty of projects. Therefore, the author suggests models based on the utility theory, in which the risks and the manager’s features can be incorporated.

In this context, the purpose of this study is to evaluate the optimal level of participation in mining projects subjected to uncertainties and risks, carried out through joint ventures. Specifically, the uncertainties and the risk of a granite mining project are submitted to a test model in order to determine the optimal level of participation in this business venture so to maximize its expected utility from a decision maker.

Besides this introduction, this article has four sections. the second one focuses on the characteristics of the based models on cash flow discounting and utility theory. In section three the methodological procedures to be used are presented. The discussion is conducted in section four. Finally, in section five, the final considerations are made.

2. THEORETICAL REFERENTIAL

2.1. Economic analysis of projects using the Discounted Cash Flow model

An investment project can be classified as a set of technical and monetary information of the inputs needed for production and the actual production itself, trying to simulate the decision to invest and its implications (12). Note that the present work will be about an investment project directed to the mining activity. For the project be economically feasible, the benefits generated by the production process must exceed the costs of production, ie, the benefit-cost ratio should be higher than one (13).

After the budgets are elaborated, so-called cash flows are constructed, and from these are calculated the profitability indicators of the project, which will allow to illustrate the economic potential of the same. Cash flows are composed of the initial investment, operating cash inflows and residual cash flow, and used to make capital budget decisions (14).

According to (15), the project analysis will be fully satisfactory, if and only if some essential steps be effectuated, namely: financial evaluation and economic evaluation, financial being a means of measuring the profitability of a project (16). That is, the Net Present Value (NPV) is the difference between the values present at a rate (r) discounted, and the initial investment (11):

\[ NPV = \sum_{t=1}^{T} \frac{FCt}{(1+r)^t} - I \]  

(1)

This way, projects with NPV greater than zero should be accepted. On the other hand, if the NPV is less than zero, they should be refused. If the NPV is equal to zero, the decision to invest in the projects is indifferent (3). The IRR of a project is the discount rate that equates the values of the future value of flow cash to the initial investment. In this case, the decision
to investment in a project should be only if IRR is greater than a Minimum Acceptable Rate of Return (MARR) (17).

$$\sum_{t=1}^{n} \frac{F C_t}{(1 + i_{\text{IRR}})^t} = 1$$

(2)

In its turn, the payback period indicates the number of periods (years, months, etc.) required to recover the expenses generated for the implementation of the project (18). According to (11), by employing this method, the most viable project is the one which presents lower payback in relation to a deadline set by the manager.

The present theme it is frequently exploited in the mining scientific literature, as it is possible to be found in (19, 20, 21). In addition, the process of modeling complex systems involves the construction of elaborated theories and models in order to solve real problems, in this way, the standard feasibility economics models become more robust, including some topics, as risk, uncertainty and the decision process involving different actors that requires strategy. According to that, the “modern economic analysis” involves a huge number of correlated areas, as microeconomic formulation, games theory analysis, real options and dynamic programming methods. A piece of works in this way can be found in (22, 23, 24, 25, 26).

2.2. Economic analysis using the choice under uncertainty theory

The risk it is a variable inherent to all kinds of processes and has a strictly influence on the economic agents’ choices, in this sense; it is possible to say that individual choices are nothing more than decision-making processes under uncertainty. In this context, it is important to know how a particular economic agent it is risk-willing or risk-averse. According to that, the ability to measure risks it is full of importance the agents. In general terms, it is assumed an inversely proportional relationship between risk and return is, i.e. the expected return on an investment will be greater as its risk is higher. In order to illustrate the theory, it is possible to say some investor will not be willing to buy a debt security of a given country, living a huge crisis, e.g. like a war. The way to attract investors it is paying an attractive interest rate, so, the return it is opposite to the risks. Different examples can be found as the classic one: the lottery and the associated premium. (27)

The aforementioned theory gained momentum with (28) seminal work, which aimed to measure the degree of risk aversion of a given agent and is a recurrent theme in the literature (29, 30, 31). The Arrow formulation is based on the above Equations, (3) and (4):

$$A = - \frac{U''(x)}{U'(x)}$$

(3)

$$A' = -x \frac{U''(x)}{U'(x)}$$

(4)

where: A = absolute risk aversion measure and A’ = relative risk aversion measure.
To illustrate graphically the problem, Chart 1 presents the utility function in three general aspects: concave, linear and convex and the associated effect of these curves on the economic agent’s level of taking risks. The present debate is strongly explored in the Microeconomic Theory as it is possible to see in the following works: (32, 33, 34).

![Chart 1 - The utility function according to the risk](image)

Legend: $U(x) = \text{utility of } x$; $E[U(x)] = \text{expected value of } x$; CE = certainty equivalent; RP = risk premium

Source: (35).

Specifically, the presence of uncertainty in projects disqualifies the investment decision using models based on discounted flow cash. Therefore, the literature suggests the use of models based on utility theory (choice under uncertainty) (36), incorporates the risks and the manager preferences for them: aversion, neutrality or propensity. According (4), “[...] quantification is performed by associating an abstract utility value for each of the possible situations.”

In this regard, the Utility of Expected Value (VEU) and Expected Monetary Value (VME) are tools that define the investor's preference on a choice and if the investment should be abandoned or not. (4). The utility function is used as the most appropriate for expressing a preference from the decision maker. Algebraically, the exponential utility function is more appropriate for facilitating the modeling of risk aversion coefficient (4). The aversion coefficient will be given by the monetary portion, venture capital, the investors are willing to lose, so to conceptualize the risk tolerance.

The probability ($P_i$) of the occurrence of risk, regarding risk tolerance ($c$) may represent the willingness to abandon the project, and the amount accepted by the investor to give up his purchase and guarantee free amount of risk is called the certainty equivalent (37).

$$\varepsilon = \frac{1}{e} \times \ln \left[ p_1 \times e^{-cNPV_1} + e^{-cNPV_2} \right]$$
The certainty equivalent of the optimum level of participation depends “on the level of investment given by the investor's risk tolerance the risk tolerance levels may vary [...] to assess the level of optimized investment and their participation in the project” (36).

In order to maximize the certainty equivalent, investors strategically decide for creating joint ventures, in which the cash flow is divided among participants in proportion to their Financial Participation Level (FPL) in the enterprise. To determine the optimal FPL we should solve a maximization problem to fit the best value of EqC:

$$\text{Max: } EqC = -\frac{1}{c} \ln \left( \sum_{i=1}^{n} P_i * e^{-FPL_i * NPV * c} \right)$$

Limited to: $FPL \leq FPL_{\text{maximum}}$

3. Material and Methods

As mentioned in the introductory section, this research intended to assess the optimal level of participation in a granite mining project which is susceptible to uncertainty and risk. In this way, it is an applied, quantitative and predictive research which takes into consideration the classification proposed by (38).

Data were collected from an Economic Exploitation Plan presented by a mining company in the state of Minas Gerais to the National Department of Mineral Production (DNPM), which is the federal entity responsible for analyzing the economic feasibility of extraction projects, as well as processing and marketing of mineral reserves. It is noteworthy that, according to Article 38, chapter VII of the Mining Code. - Decree-Law No. 227 of February 28, 1967, it is mandatory the presentation of an Economic Exploitation Plan to require the mining of any mineral substance. In order to protect the confidentiality of the company, some data were changed. However, it does not harm the effectiveness of the applied methodology.

To obtain the economic viability of the project indicators (NPV, IRR and payback), Microsoft Excel financial functions were used. The uncertainty modeling was made with the software @RISK student version, which works in integration with Excel. 10,000 iterations were performed so that the investment, the sale price and the production costs were admitted as stochastic variables.

Then, the risk of the project was achieved, ie, the probability of loss financial (NPV lower than zero). Finally, through the Excel Solver tool the Financial Participation level (FPL) that maximizes the expected utility of the project was determined.

4. ANALYSIS AND RESULTS DEMONSTRATION

4.1. Analysis of the economic viability indicators

Table 1 highlights the design parameters considered in the economic viability analysis. It is possible to see the principal information utilized in the analysis, as the
investigation value, the mineable reserve, useful life time, extractions rate, sale price, variable costs, depreciation rate, income tax and interest rate (Selic).

Table 1 - project parameters

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment (non-recoverable)</td>
<td>R$5,000,000.00</td>
</tr>
<tr>
<td>Mineable Reserve</td>
<td>7,500 tons</td>
</tr>
<tr>
<td>Useful life</td>
<td>5 years</td>
</tr>
<tr>
<td>Extraction rate</td>
<td>1,500 tonnes/year</td>
</tr>
<tr>
<td>Sale price</td>
<td>R$1,000.00/ton</td>
</tr>
<tr>
<td>Variable Costs</td>
<td>R$300,000.00</td>
</tr>
<tr>
<td>Depreciation</td>
<td>20%</td>
</tr>
<tr>
<td>Income tax</td>
<td>15.00%</td>
</tr>
<tr>
<td>MRA (Selic Rate)</td>
<td>14.25% p.a.</td>
</tr>
</tbody>
</table>

Source: Produced by the author from the altered data in the PAE project and the adjustment of probability distribution (2017).

Table 2 shows the cash flow of the project. It’s considered that the NPV is positive, indicating that this project is feasible. This is confirmed by its IRR, (22.64% p.a.) which is greater than the MRA. In this scenario, the simple payback of the project is 3.82 years and discounted payback, 4.92 years.

However, the variables uncertainty of variables influenced directly the value of NPV. Thus, it was considered the uncertainties shown in Table 3, according the triangular distribution. According to (39) it is possible to say that the triangular distribution generates a simplistic probability distribution representation when limited sample data is available. The distribution parameters are: minimum, maximum, and data peak. This distribution is widely utilized in business, economic simulations, project management planning and modeling.
Table 2 - project cash flow in thousands of Reais.

<table>
<thead>
<tr>
<th>Year</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-5,000.00</td>
<td>1,200.00</td>
<td>1,200.00</td>
<td>1,200.00</td>
<td>1,200.00</td>
<td>1,200.00</td>
</tr>
<tr>
<td>Investment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Price</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Annual revenue</td>
<td>1,500.00</td>
<td>1,500.00</td>
<td>1,500.00</td>
<td>1,500.00</td>
<td>1,500.00</td>
<td>1,500.00</td>
</tr>
<tr>
<td>Fixed operating cost</td>
<td>400.00</td>
<td>400.00</td>
<td>400.00</td>
<td>400.00</td>
<td>400.00</td>
<td>400.00</td>
</tr>
<tr>
<td>Variable operating cost</td>
<td>300.00</td>
<td>300.00</td>
<td>300.00</td>
<td>300.00</td>
<td>300.00</td>
<td>300.00</td>
</tr>
<tr>
<td>Profit before taxes</td>
<td>800.00</td>
<td>800.00</td>
<td>800.00</td>
<td>800.00</td>
<td>800.00</td>
<td>800.00</td>
</tr>
<tr>
<td>Before-tax cash flow</td>
<td>-5,000.00</td>
<td>1,200.00</td>
<td>1,200.00</td>
<td>1,200.00</td>
<td>1,200.00</td>
<td>1,200.00</td>
</tr>
<tr>
<td>Depreciation</td>
<td>1,000.00</td>
<td>1,000.00</td>
<td>1,000.00</td>
<td>1,000.00</td>
<td>1,000.00</td>
<td>1,000.00</td>
</tr>
<tr>
<td>Taxable Profit</td>
<td>200.00</td>
<td>200.00</td>
<td>200.00</td>
<td>200.00</td>
<td>200.00</td>
<td>200.00</td>
</tr>
<tr>
<td>Income tax</td>
<td>30.00</td>
<td>30.00</td>
<td>30.00</td>
<td>30.00</td>
<td>30.00</td>
<td>30.00</td>
</tr>
<tr>
<td>Profit after the taxes</td>
<td>770.00</td>
<td>770.00</td>
<td>770.00</td>
<td>770.00</td>
<td>770.00</td>
<td>770.00</td>
</tr>
<tr>
<td>After-tax cash flow</td>
<td>-5,000.00</td>
<td>1,770.00</td>
<td>1,770.00</td>
<td>1,770.00</td>
<td>1,770.00</td>
<td>1,770.00</td>
</tr>
<tr>
<td>Discounted after-tax cash flow</td>
<td>-5,000.00</td>
<td>1,549.234</td>
<td>1,356.003</td>
<td>1,186.874</td>
<td>1,038.839</td>
<td>909.268</td>
</tr>
</tbody>
</table>

Source: Produced by the author (2017)

Table 3 - uncertainties in cash flow

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Distribution</th>
<th>Minimum</th>
<th>More Likely</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment</td>
<td>Triangular</td>
<td>R$ 4,500,000.00</td>
<td>R$ 5,000,000.00</td>
<td>R$ 6,000,000.00</td>
</tr>
<tr>
<td>Granite price</td>
<td>Triangular</td>
<td>R$ 600.00</td>
<td>R$ 1,000.00</td>
<td>R$ 1,100.00</td>
</tr>
<tr>
<td>Variable cost</td>
<td>Triangular</td>
<td>R$ 90,000.00</td>
<td>R$ 300,000.00</td>
<td>R$ 800,000.00</td>
</tr>
</tbody>
</table>

Source: Produced by the author (2017).

Consequently, the NPV of the project has no single value, but a probability distribution in which the cumulative value is illustrated in Chart 2. So, considering the probability of negative NPV, the risk of the project is 25.74%. In this case, the financial loss is R$ 216,968.63, on average whereas in viable scenarios, the NPV is of R$ 369,843.06.
4.2. Assessment of optimal level of financial Participation

In this stage the project optimal level of financial Participation was determined. Assuming the company has R$4,000,000.00 to invest, which is not enough to required R$5,000,000.00 in order to accomplish the project. It was considered that there is no interest in taking out loan from third parties, which indicates that a partnership should be created to implement the project. The company will have maximum participation of 80% in the business. The parameters considered in this analysis are shown in Table 4.

Chart 3 illustrates the impact of the level of financial participation on the EqC. Note that the value of the EqC assumes maximum value when the level of financial participation is between 50 and 60%.

In fact, by solving the problem of optimization of the EqC, it was found that the level of financial participation equal to 54.29% maximizes it. That means the company must finance 54.29% of the project, which represents R$ 2,714,418.05. The company is expected to get the same NPV percentage from the project: R$ 118,781.70. These results indicate that in the formation of the joint venture the company shouldn't employ all available investment budget.
Table 4 - parameters of the analysis for the optimal level of financial participation.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment</td>
<td>R$ 5,000,000.00</td>
</tr>
<tr>
<td>Average NPV (failure)</td>
<td>R$-216,968.63</td>
</tr>
<tr>
<td>p (failure)</td>
<td>25.74%</td>
</tr>
<tr>
<td>Average NPV (success)</td>
<td>R$ 369,843.06</td>
</tr>
<tr>
<td>p (success)</td>
<td>74.26%</td>
</tr>
<tr>
<td>Budget</td>
<td>R$ 4,000,000.00</td>
</tr>
<tr>
<td>Coefficient of risk tolerance</td>
<td>0.05</td>
</tr>
<tr>
<td>Risk tolerance</td>
<td>R$ 200,000.00</td>
</tr>
<tr>
<td>Maximum level of financial participation</td>
<td>80%</td>
</tr>
</tbody>
</table>


Chart 3 - The certainty equivalent susceptibility of the financial participation level

Source: Drawn by the author (2017).
5. FINAL CONSIDERATIONS

In this study we assessed the optimal level of participation in a granite mining project which is susceptible to risks and uncertainties, implemented through joint venture model. It is considered the initial investment, the sales price and the cost of production of the mineral as if they were uncertainties, which involved risks of financial losses.

The investment is feasible, analyzed by the discounted cash flow (DCF) model, with positive NPV and IRR greater than MRA. However, probabilistic distributions of uncertainty factors prevent a fixed VPL value, showing, by means of simulation, high standard deviation, which makes the project susceptible to failure. The utility theory incorporates the risks and uncertainties in their analysis, being possible to calculate the level of financial participation in a partnership, does not need the investment of any budget.

The results suggest that incorporate risk factors and uncertainty in projects is a risk aversion strategy that allows for reliability under decision-making. The method of evaluation through DCF presents limitations when it comes to uncertainties and risks, which are incorporated by the utility theory. The strategic formation of a joint venture allows investments that are considered risky made possible by the Division of cash flows in proportion to the level of financial participation each one has.

The establishment of the optimal level of participation on multiple projects susceptible to uncertainties and risks is an interesting suggestion of continuity for this research, especially because it did not show how part of uninvested budget should be applied.

6. References


7. Correspondence

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