Stochastic economic feasibility assessment and risk analysis of a quarry mine focusing on the Brazilian tax system

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Abstract

An economic feasibility study must consider the uncertainties inherent to a mining project, whose risks must be quantified properly to enable accurate decision-making. Studies previously carried out through the Discounted Cash Flow (DCF) methodology in the project evaluated here - a quarry whose operations are currently interrupted, located in Pernambuco, Brazil, formerly taxed under the presumed profit regime - indicated a positive Net Present Value (NPV) in the deterministic scenario, therefore projecting a profitable project. However, a probabilistic analysis using Monte Carlo simulations indicated only a 49.98% occurrence probability for this NPV. An assessment focused on the company's taxation was never carried out, which is a gap that the present study intends to fill, in addition to evaluating the feasibility of immediate investment in this project. Furthermore, this is a gap in Brazilian literature in general, which does not take into account the taxation system in their economic assessments. In this context, considering scenarios whose taxation was based on real and presumed profit regimes, we reassessed the cash flows of this quarry and performed deterministic and probabilistic economic analyses, and compared the results of both scenarios. The sensitivity analysis indicated that the production rate would be the most impactful variable in the project's NPV, considering the six variables assessed. Hence, it was verified in both deterministic and probabilistic analyses that taxation under real profit, results in a higher economic return with a 56.08% probability of the NPV being positive and with the Internal Rate of Return (IRR) higher than inflation (SELIC rate) at 4.81%; the taxation under the presumed profit, on the other hand, obtained respective probabilities of 46.54% and 3.23%. However, with the chances of obtaining some profit (NPV greater than zero) at the order of 50% and a minimal chance of the IRR being greater than the SELIC rate adopted at the time of this study, we would advise against investing in this venture. Moreover, even if the current moment is not the most suitable for investment in this sector, regardless of the production rate assessed in the probabilistic analysis, taxation on the real profit regime presented a greater economic return than taxation on the presumed profit regime., indicating that, for the parameters considered in this study, the first would be the most appropriate choice of tax system for this type of enterprise in Brazil.

keywords: mineral economics, stochastic economic feasibility study, Monte Carlo simulations, Brazilian tax system.

1. Introduction

A mining project involves three stages, which are the conceptual, pre-feasibility and economic feasibility studies. However, to enable the two final phases, it is necessary to define the production rate and the lifespan of the company, among other variables, although most of the information is still speculation at this phase (Mariz, 2018). Variations in boundary conditions can have a significant impact on ultimate pit determination, production scheduling, cash flows and on a final project return of millions of dollars (Dimitrakopoulos *et al*., 2002; Peroni, 2002). The large number of parameters and the numerous sources of uncertainty must be identified properly in the process of project elaboration due to the great financial risk inherent to the decision making at this stage, where risks can be classified as geological, economic and socio-political (Cherchenevski *et al*., 2019).

In both fledgling and operating mines, cash flow and risk management are critical to project success. Choosing a reduced production rate extends cash flows, delays revenue and reduces potential profits, which will only be realized after many years of operation; on the other hand, choosing aggressive production rates increases capital costs and payback time, although it tends to maximize economic returns (Mariz, 2018). The economic feasibility study must encourage the reduction of impacts to the environment, consider the stability of the mine and be flexible to geological conditions and available infrastructure. In addition, it must contemplate different scenarios, seeking to achieve maximum productivity and reduce unitary and global costs, analyzing different cutoff grades, mining and processing equipment, as well as production rates, selling prices, inputs, miscellaneous costs, among others (Rocha *et al*., 2018; Darling, 2013).

After pondering the necessary constraints and considering a Minimum Acceptable Rate Of Return (MARR), a deterministic Discounted Cash Flow (DCF) analysis provides indices, such as Net Present Value (NPV) and Internal Rate Of Return (IRR) for a scenario, thus requiring uniform periods (annual periods, for instance) to basically confront cash benefits against costs, adjusting their values over time. However, as deterministic economic analysis presupposes that the constraints are precisely known and constant over time, it is necessary to measure the risk inherent to these assumptions through techniques such as stochastic risk analysis and sensitivity analysis (Darling, 2013; Gentry & O'Neil, 1996; O'Neil & Gentry, 1996).

On the other hand, considering that key variables comprise a range of feasible values rather than a deterministic value, generally transforming them into continuous probability distribution functions, the stochastic economic evaluation methodology randomly samples these statistical domains using Monte Carlo Simulations or some other technique to retrieve one or more outcome distribution functions, such as NPV and IRR. Hence, once the outcome distributions have been created through exhaustive iterations, risk can be measured by determining the probabilities of exceeding reference levels in the histogram, the probability that the project's NPV is greater than zero, for example (O'Neil & Gentry, 1996).

Regarding risk assessment for engineering purposes in mining, the studies of Vargas *et al*. (2014), Charbel (2015) and Zhang & Huang (2016) exemplify the technique. In addition, regarding the stochastic economic evaluation in open-pit mining projects, the studies of Cardin *et al*. (2008), Wei *et al*. (2011), Petter (2015), Souza (2017), De Assis (2019), Omotehinse & De Tomi (2021) and Mariz *et al*. (2021) can provide applications for different mineral substances and purposes. In turn, Cavalcante (2019) and Cavalcante *et al*. (2019) carried out deterministic and probabilistic economic feasibility studies at the Pedreira Esperança quarry, a company located in Pernambuco, Brazil, which produced aggregates for civil construction and which ceased operations for economic reasons, being also the company we assessed in this study. The focus of the previous studies was to assess the impact of the size of the excavators on the project's NPV. For the probabilistic analysis, the authors converted the variable's monthly production rate, MARR, average sale price, costs of fuel, electricity and emulsion explosive into triangular and PERT statistical distributions, and then proceeding to Monte Carlo simulations and a Sensitivity Analysis, reaching a 49.98% probability of occurrence of the positive NPV achieved in the deterministic analysis (Cavalcante, 2019; Cavalcante *et al*., 2019).

It is worth highlighting that Brazilian tax regimes have very different characteristics, and adopting one of them requires a thoughtful and assertive decision, since there are several details that influence the calculation of total taxation and the pursuit for the least onerous regime. Depending on the annual revenue and the corporate structure, in addition to other particularities, a given company may opt for the real profit, presumed profit, arbitrated profit and national simple regimes, although in this study only the former two were regarded, due to their suitability for the size and characteristics of the mining companies. Concisely, the main differences between these tax regimes lie in the calculation basis and in the rates of PIS/PASEP (*Programa de Integração Social/ Programa de Formação do Patrimônio do Servidor Público* - Social Integration Program/ Public Servant Asset Formation Program), COFINS (*Contribuição para Financiamento da Seguridade Social* - Contribution to Social Security Financing), IRPJ (Imposto de Renda Pessoa Jurídica - Corporate Income Tax) and CSLL (*Contribuição Social sobre o Lucro Líquido* - Social Contribution on Net Income) taxes. While the presumed profit presupposes that the company always makes a profit and is levied on this presumption, the real profit allows for a taxation more consistent with the company's reality, in addition to considering the previously calculated loss discount, but some of its rates are higher than the presumed profit regime (Amaro, 2016; Crepaldi, 2019).

That said, the real profit is net income for the period adjusted for additions, exclusions or offsets, and to obtain this taxable amount, deductions, costs and operating expenses must be subtracted from gross revenue, as well as adding any other income and subtracting non-operating losses. Hence, the CSLL (9%) and the IRPJ (15% on the calculated profit with an additional 10% on the portion of the profit that exceeds BRL 20,000.00 per month) are levied on the accounting result of the mining company, which would be the gross revenue plus capital gains, less deductible expenses, PIS/PASEP (1.65%) and COFINS (7.6%), which are levied on gross sales revenue. The non-cumulative regime of PIS/PASEP and COFINS consists of deducting from the debits calculated for each contribution of the respective credits allowed by law; the main objective would be avoiding the cascading incidence of contributions, allowing credit in the purchase of certain goods, services and inputs. Depreciation and amortization charges for machinery, equipment and other assets incorporated into property, plant and equipment, as well as charges for depreciation and amortization of buildings, also subject to credit. Finally, the offset of tax losses calculated in the previous year, limited to 30% of the adjusted net income, has an indefinite period for prescription and offset in future years (Crepaldi, 2019).

In turn, the presumed profit consists of a percentage of gross revenue in the calculation period plus capital gains, income and net gains earned on financial investments, and only mining companies earning up to BRL 78,000,000.00 per year can operate under this regime. Thus, both IRPJ and CSLL are calculated based on the presumed profit, with the IRPJ corresponding to the presumption of 8% of gross revenue, followed by 15% of the base rate plus 10% when the portion of the presumed profit exceeds BRL 60,000.00 per quarter. In addition, the CSLL corresponds to the presumption of 12% of gross income, followed by 9% of the base rate. PIS/PASEP (0.65%) and COFINS (3%) are calculated cumulatively and are levied only on gross sales (Crepaldi, 2019). Regarding taxes which are also applicable to mining companies,

we highlight the CFEM (*Compensação Financeira pela Exploração Mineral* - Financial Compensation for Mineral Exploration), which is levied on 1% of the quarries' gross revenue, and the ICMS (*Imposto sobre Circulação de Mercadorias e Prestação de Serviços* - Tax on Movement of Goods and Provision of Services), which, in the State of Pernambuco, is equivalent to 18% of the gross revenue; however, with an incentive from the state government, this percentage receives a discount of 75%, totaling 4.5% on gross sales.

As the Pedreira Esperança quarry has always operated under the presumed profit regime and the replacement of the tax regime was never considered, this study aims to fill this gap, by carrying out deterministic and probabilistic economic feasibility assessments, considering the resumption of the enterprise by the tax systems real profit or presumed profit and evaluating under which circumstances it would be advisable to invest in it immediately. To this end, we compare indicators such as NPV, IRR and percentage of taxes on gross revenue in both deterministic scenarios, as well as performing sensitivity and risk analyzes in both probabilistic scenarios, enabling accurate decision-making about the best tax regime for the resumption of this enterprise. We obtained the acquisition values of the equipment from the suppliers, while the costs of inputs considered in the deterministic scenario represent the values practiced at the time of this study, as well as the sales prices of the aggregates are those practiced by quarries in the same region as the quarry studied here. More information on deterministic and probabilistic economic evaluations of mineral enterprises can be obtained from Gentry & O'Neil (1996), O'Neil & Gentry (1996), Cavalcante (2019) & Cavalcante *et al*. (2019), while more information on Brazilian tax law and its different taxation systems can be obtained from Amaro (2016) and Crepaldi (2019).

2. Materials and methods

2.1 Characterization of the studied area

According to the calculation of mineable reserves carried out by Cavalcante (2019), Pedreira Esperança, located in Pernambuco, Brazil, has the equivalent of 5,559,986.28 m³ of in situ rock (or 8,339,979.42 m³ with a blistering of 1.5) and 223,308.82 m³ of in situ overburden (or 312,632.348 m³ with a blistering of 1.4). Considering a 44-hour weekly regime, the primary jaw crusher would produce 49,147.96 m³/month, with efficiency attached to the excavator-trucks set, while the secondary processing plant, with two cone crushers with an estimated efficiency of 90%, would produce 23,513.38 m³/month. If a night shift of the secondary plant of 40 hours per week is desired, another 21,331.73 m³/month would be produced, resulting in the secondary plant's capacity to produce 44,845.11 m³/month, which is the maximum global processing capacity (Cavalcante, 2019).

Cavalcante (2019) and Cavalcante *et al*. (2019) showed that the maximum capacity of the Caterpillar 336 excavator would be 209.09 m³/h, while the haul trucks with 12 m³ of capacity, respecting the average transport distances along the mine's lifetime, would be 71.89 m³/h. Thus, three transport units would be enough to reach the maximum capacity of the excavator-truck set. However, considering the excavator's efficiency at 83%, its maximum capacity becomes 173.54 m³/h. Table 1 presents the equipment formerly in operation at the company and its depreciation periods, which are considered in the development of this study (Cavalcante, 2019; Cavalcante *et al*., 2019).

Table 1 - List of Pedreira Esperança equipment and their respective depreciation.

Equipment	Units	Depreciation (Years)
Drill rig PW 5000	1	10
Air compressor Atlas Copco XAS 420	1	10
Excavator Caterpillar 336	1	10
Excavator Hyundai R210 LC-7	1	10
Wheel loader Caterpillar 924	1	10
Wheel loader Shantui SL 15W3	1	10
Haul trucks Ford Cargo 12m³	3	5
Jaw crusher Metso C100	1	15
Cone crusher Sandvik CS 430	1	15
Cone crusher Metso HP 200	1	15

Source: Adapted from Cavalcante (2019).

2.2 Methodology

After defining the mineable reserves, the equipment, their productive capacities and working hours, the deterministic economic analysis was carried out. We estimated the company's annual gross revenue from the average sales value of different products multiplied by the annual production rate, and we obtained equipment acquisition costs from suppliers and operating costs from the company's history. The annual costs with taxes, contributions and compensations were computed in two different scenarios, considering the adoption of the real profit or presumed profit regimes by the company. Depreciation was computed as a tax incentive, while amortization and depletion were not because investment with private equity was simulated and the deposit belongs to third parties. After the depreciation of each equipment, we considered the acquisition of a new one and the sale of the old one for a

residual value of 30% of the new one, with a rate of 15% on the profit from such sale. If the sale took place in the mine closure year and the equipment had not been fully depreciated, a percentage proportional to its time of use would be calculated, but never less than 30% of its purchase value. We also considered the removal of the overburden with leased equipment during the first eleven years; in the last year of the project, this material returns to the pit and a project to plant native forest is followed up for another four years after the mine closure.

After composing the cash flows, we calculate the project's NPV and IRR for a given TMA, considering deterministic values based on average or real values consulted with suppliers and/or surrounding quarries. The TMA selected was 8.5%, consisting of an expected profit equivalent to twice the SELIC rate at the time of the study, equivalent to 4.25%. Considering the precariousness of this deterministic economic assessment in face of project uncertainties, sensitivity and probabilistic risk analysis were also performed, transforming the most impacting variables into probability distribution domains and randomly sampling values in these from Monte Carlo simulations. Figure 1 presents the Pert and triangular probability distribution functions representing the six transformed variables, i.e. monthly production rate (m³), annual SELIC (MARR) (%), average sale price (BRL/m³), cost of fuel (BRL/L), electric energy (BRL/kWh) and emulsion explosive (BRL/kg). In turn, Table 2 presents the most probable value, as well as the lower and the upper bounds of the the statistical domain of each variable.

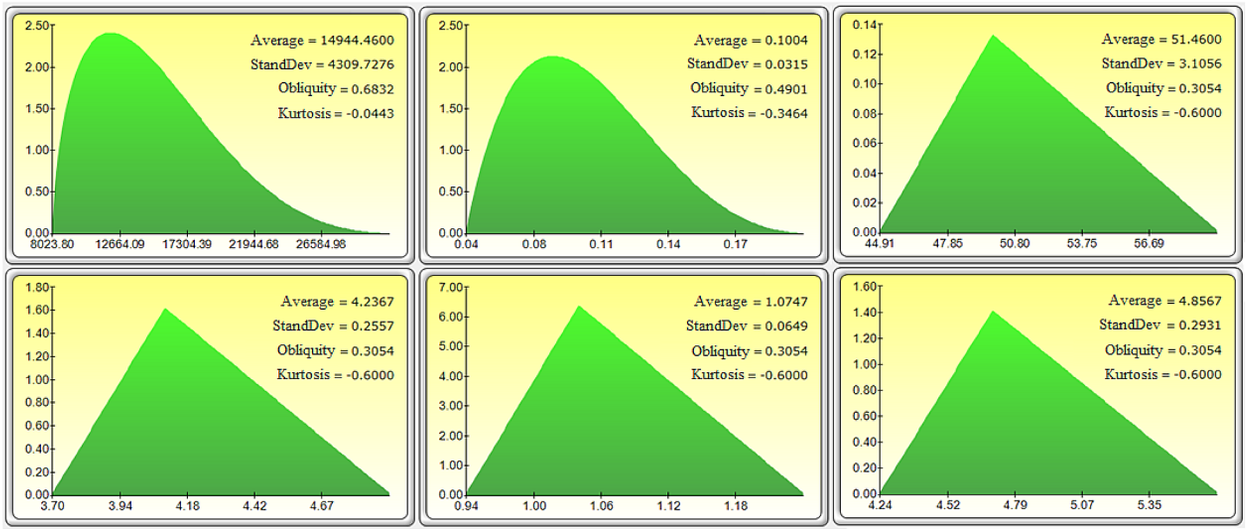

Figure 1 - Probability distribution models of the six variables defined as influencing the enterprise, i.e. Monthly production rate (m³), Annual SELIC (MARR) (%), Average sale price (BRL/m³), Cost of fuel (BRL/L), Electric energy (BRL/kWh) and Emulsion explosive (BRL/Kg), respectively.

Table 2 - Functions and bounds representing the statistical domain of each variable.

Input variable	Function	Minimum	Probable	Maximum
Monthly production rate (m³)	Pert	8,000	12,000	33,667
Annual SELIC (MARR) (%)	Pert	4.250	8.500	22.000
Average sale price (BRL/m³)	Triangular	44.820	49.800	59.760
Cost of fuel (BRL/L)	Triangular	3.690	4.100	4.920
Electric energy (BRL/kWh)	Triangular	0.936	1.040	1.248
Emulsion explosive (BRL/Kg)	Triangular	4.230	4.700	5.640

As aforementioned, the most likely values adopted are those practiced at the time of the study. The minimum values are equivalent to 90% of the probable value or limits considered plausible, as production rates lower than 8,000 m³ or a TMA lower than 4.5% would be unfeasible. On the other hand, the maximum values are equivalent to 120% of the probable value (in most cases), although the maximum capacity of the equipment and the highest value presented by the SELIC rate in the last 20 years also served as reference.

From the definition of the six statistical domains, 100,000 Monte Carlo simulations were done in the Risk Simulator 2017 software for each tax modality, considering the NPV as an output; hence, it was possible to perform a sensitivity analysis that indicated which variable among the analyzed ones most impacted the NPV of the enterprise. From that, risk analyzes were performed, in which another 100,000 Monte Carlo simulations were carried out for each tax modality, this time considering the NPV and the IRR as output, but only including as input the most impacting variables determined during the sensitivity analysis.

Furthermore, this process resulted in histograms of simulated NPV and IRR for each tax regime; these numbers were then independently evaluated by reaching the probabilities of a positive NPV, as well as higher than the deterministic NPV. In addition to that, the probabilities of the IRR considered being higher than the interest rate in Brazil (SELIC rate) during this study, as well as being higher than the most likely MARR, therefore providing robustness to the analysis and more accurate decisions than those based solely on deterministic economic analyses.

3. Results and discussion

3.1 Deterministic economic assessment

The company's gross revenue is BRL 597,600 per month or BRL 7,171,200 per year, considering the average sale price at 49.80 BRL/m³ and the production rate equivalent to 12,000 m³. The eventual sale of depreciated equipment is also added to the cash flow corresponding to the sale period. On the other hand, since capital expenditures (CAPEX) are the investments necessary for the full operation of the enterprise, they have to be computed at the beginning of the cash flow. This is an atypical case of the resumption of an enterprise that was interrupted, since the infrastructure works, earthworks, dependencies and workshops have already been built. Thus, in this study we consider CAPEX as just the acquisition of new equipment, installation of the beneficiation plant, miscellaneous costs and working capital. Plant installation involves renting cranes, skilled labor, electrical installation, among others. Miscellaneous costs involve preparing offices, workshops and warehouse with the basics to start the operation. Working capital was estimated at twice the monthly operating cost, to make up for the immediate lack of capital due to the deadlines granted for payment of products sold. Table 3 presents the CAPEX mentioned, whose total is estimated at BRL 7,548,420.07.

Table 3 - Capital Expenditure (CAPEX).

Capital Expenditure (CAPEX)	Cost (BRL)
Equipment	6,238,350.00
Processing plant installation	150,000.00
Miscellaneous costs	50,000.00
Working capital	1,110,070.07
Total	**7,548,420.07**

Operational expenditures (OPEX), in turn, regard the enterprise operation, and in the present analysis involve fuel, wear material, tires, electricity, explosives, lease and payroll. The lease consists of the payment of 4% of the billing, or a minimum installment of BRL 25,000.00 per month, resulting in BRL 300,000.00 per year. The cost of freight was estimated at 5.83 BRL/m³. The blasting plan considers a 2 x 4-meter mesh, with a bench height of 14 meters; the hole diameter is 3", with 0.62 kg/m³ being the load rate achieved with the emulsion explosive. Mobile equipment requires fuel, lubricants, predictive and corrective maintenance, in addition to their respective wear materials (drilling, tracks, shells, tires, etc.). The processing plant demands electrical energy, screens, jaws, coatings, lubricants, belts and rollers. Staff costs include salaries, unhealthy and hazardous work compensations, night shift, INSS and FGTS taxes, vacations and thirteenth salaries, in addition to meals and personal protective equipment (PPE). General fixed costs refer to the office, workshops and support vehicles. Table 4 presents the details of OPEX, whose total is estimated at BRL 6,551,034.93 per year.

Table 4 - Main operational expenditure (OPEX).

Operational Expenditure (OPEX)	Costs (BRL/year)
Lease	300,000.00
Freight	917,875.40
Drilling	279,603.61
Blasting	312,727.26
Loading and Haulage	1,001,515.56
Loadout	482,198.16
Processing	794,429.26
Staff	1,838,965.68
General fixed costs	623,720.00
Total	**6,551,034.93**

We stipulated that the stripping would take place one month per year over 11 years, thus diluting the operation costs by BRL 109,385.48 per year, considering the rent of an excavator, a bulldozer and two trucks, all with operators. Although not detailed in Table 4, the stripping cost was included in the working capital calculation. However, after the mining closure, it is necessary to proceed immediately with the environmental rehabilitation of the area. Therefore, we considered that all the overburden returned to the pit in the last year, through the lease of the same equipment. As previously mentioned, reforestation takes place over five years, being an operation of planting, maintenance and monitoring the development of seedlings, with BRL 61,968.06 being invested over these years. As there is an Atlantic Forest reserve on the property where this project

is located, seeding costs will be significantly reduced, as seeds can be obtained on site.

After defining billings and costs, it is necessary to proceed with taxation by the two considered modalities. Table 5 presents the cash flow for a year in which no eventual operations took place (13th year) in terms of real and presumed profit regime. As presented, we consider as eventual operations the period under the influence of CAPEX, the period in which there was stripping, any years in which there was purchase and sale of equipment and the period of closure/reforestation of the mine. We made the decision to present a year that was representative of our methodology, since it would be impractical to demonstrate decades of cash flows for two tax regimes. The results of net income and percentage of taxes on gross revenue indicate that, considering the constraints assumed, the real profit regime presents better results, with a cash flow of **BRL 153,151.33** against **-BRL 224,810.82** for the presumed profit, as well as the taxation on invoicing consisting of **11.46%** and **11.78%**, respectively.

Table 5 - General enterprise cash flow in real and presumed profit regimes in a year (13th year) in which no eventual operations, such as stripping or purchase and sale of equipment, took place.

Description	Real Profit	Presumed Profit
Gross Revenue	+BRL 7,171,200.00	+BRL 7,171,200.00
Mining OPEX	-BRL 2,076,044.58	-BRL 2,076,044.58
Processing OPEX	-BRL 794,429.26	-BRL 794,429.26
General and Administrative OPEX	-BRL 2,462,685.68	-BRL 2,462,685.68
Leasing	-BRL 300,000.00	-BRL 300,000.00
Freight	-BRL 917,875.40	-BRL 917,875.40
Offsets	+BRL 354,481.27	----------
Total Expenditure	-BRL 6,196,553.65	-BRL 6,551,034.92
Depreciation	-BRL 552,080.00	----------
Expenses and Deductions	-BRL 4,029,828.71	----------
PIS/PASEP	-BRL 106,943.08	-BRL 46,612.80
COFINS	-BRL 492,586.29	-BRL 215,136.00
Previous year's compensable loss	-BRL 1,577,414.80	----------
Net profit before IRPJ and CSLL	-BRL 5,232,126.52	----------
Presumption of IRPJ (8%)	----------	BRL 552,756.10
Presumption of CSLL (12%)	----------	BRL 829,134.14
ICMS - PE	-BRL 150,253.65	-BRL 322,704.00
CFEM	-BRL 71,712.00	-BRL 71,712.00
IRPJ	-BRL 0.00	-BRL 82,913.41
Additional 10% on IRPJ	-BRL 0.00	-BRL 31,275.61
CSLL	-BRL 0.00	-BRL 74,622.07
Total Taxes	-BRL 821,495.02	-BRL 844,975.90
Total Expenditure + Total Taxes	-BRL 7,018,048.67	-BRL 7,396,010.82
Cash Flow	**+BRL 153,151.33**	**-BRL 224,810.82**
Taxes on Gross Revenue (%)	**11.46%**	**11.78%**

Therefore, in the deterministic economic analysis, we computed the cash flows up to the exhaustion of reserves, which occurs in year 57, considering a TMA of 8.5%. Hence, we reached an NPV of -BRL 6,751,239.12 for the scenario taxed by the real profit regime, while the one taxed by the presumed profit is equivalent to -BRL 11,155,308.60, both presenting a loss, as the NPVs are negative, although the former is more advantageous than the latter. Given these unprofitable conditions, it was not possible to obtain values for the IRR, indicating that the desired profits cannot be achieved. Therefore, the conditions for the most likely economic scenario, regardless of the taxation regime, are not favorable, since both the individual cash flows and the NPVs of the enterprise are negative. It is important, however, to identify the variables that most affect these results and carry out a probabilistic economic assessment with sensitivity and risk analyzes to make investors aware of the magnitude that these variables must achieve to reach the desired results.

So that other researchers can reproduce our study, we present the cash flows of the first six years of this enterprise, both by the real profit (Table 6) and by the presumed profit (Table 7), respectively, where the differences between these become more explicit.

Table 6 - Cash flows for the first six years of the enterprise on the real profit regime.

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Gross Revenue	BRL 7,171,200.00	BRL 7,171,200.00	BRL 7,171,200.00	BRL 7,171,200.00	BRL 7,171,200.00	BRL 7,171,200.00
Selling of Equipment	BRL -	BRL -	BRL -	BRL -	BRL -	BRL 150,000.00
Equipment Sales Tax	BRL -	BRL -	BRL -	BRL -	BRL -	-BRL 22,500.00
Total Revenue	**BRL 7,171,200.00**	**BRL 7,171,200.00**	**BRL 7,171,200.00**	**BRL 7,171,200.00**	**BRL 7,171,200.00**	**BRL 7,321,200.00**
CAPEX (Miscellaneous + Plant Installation Costs)	-BRL 200,000.00	BRL -	BRL -	BRL -	BRL -	BRL -
Mining OPEX	-BRL 2,076,044.58	-BRL 2,076,044.58	-BRL 2,076,044.58	-BRL 2,076,044.58	-BRL 2,076,044.58	-BRL 2,076,044.58
Processing OPEX	-BRL 794,429.26	-BRL 794,429.26	-BRL 794,429.26	-BRL 794,429.26	-BRL 794,429.26	-BRL 794,429.26
General and Administrative OPEX	-BRL 2,462,685.68	-BRL 2,462,685.68	-BRL 2,462,685.68	-BRL 2,462,685.68	-BRL 2,462,685.68	-BRL 2,462,685.68
Purchase of Equipment	-BRL 6,238,350.00	BRL -	BRL -	BRL -	BRL -	-BRL 500,000.00
Stripping	-BRL 109,385.48	-BRL 109,385.48	-BRL 109,385.48	-BRL 109,385.48	-BRL 109,385.48	-BRL 109,385.48
Leasing	-BRL 300,000.00	-BRL 300,000.00	-BRL 300,000.00	-BRL 300,000.00	-BRL 300,000.00	-BRL 300,000.00
Working Capital	BRL 1,110,070.07	BRL -	BRL -	BRL -	BRL -	BRL -
Freight	-BRL 917,875.40	-BRL 917,875.40	-BRL 917,875.40	-BRL 917,875.40	-BRL 917,875.40	-BRL 917,875.40
Offsets	BRL 354,481.27	BRL 354,481.27	BRL 354,481.27	BRL 354,481.27	BRL 354,481.27	BRL 354,481.27
Total Expenditure	**-BRL 11,634,219.06**	**-BRL 6,305,939.13**	**-BRL 6,305,939.13**	**-BRL 6,305,939.13**	**-BRL 6,305,939.13**	**-BRL 6,805,939.13**
Depreciation	-BRL 552,080.00	-BRL 552,080.00	-BRL 552,080.00	-BRL 552,080.00	-BRL 552,080.00	-BRL 552,080.00
Expenses and Deductions	-BRL 4,384,309.98	-BRL 4,029,828.71	-BRL 4,029,828.71	-BRL 4,029,828.71	-BRL 4,029,828.71	-BRL 4,029,828.71
PIS/PASEP	-BRL 106,943.08	-BRL 106,943.08	-BRL 106,943.08	-BRL 106,943.08	-BRL 106,943.08	-BRL 106,943.08
COFINS	-BRL 492,586.29	-BRL 492,586.29	-BRL 492,586.29	-BRL 492,586.29	-BRL 492,586.29	-BRL 492,586.29
Previous year's compensable loss	-BRL 1,235,573.54	-BRL 1,499,901.23	-BRL 1,579,199.53	-BRL 1,602,989.02	-BRL 1,610,125.87	-BRL 1,612,266.92
Net profit before IRPJ and CSLL	-BRL 4,118,578.48	-BRL 4,999,670.75	-BRL 5,263,998.44	-BRL 5,343,296.74	-BRL 5,367,086.23	-BRL 5,374,223.08
Presumption of IRPJ (8%)	BRL -	BRL -	BRL -	BRL -	BRL -	BRL -
Presumption of CSLL (12%)	BRL -	BRL -	BRL -	BRL -	BRL -	BRL -
ICMS PE	-BRL 150,253.65	-BRL 150,253.65	-BRL 150,253.65	-BRL 150,253.65	-BRL 150,253.65	-BRL 150,253.65
CFEM	-BRL 71,712.00	-BRL 71,712.00	-BRL 71,712.00	-BRL 71,712.00	-BRL 71,712.00	-BRL 71,712.00
IRPJ	BRL -	BRL -	BRL -	BRL -	BRL -	BRL -
Additional 10% on IRPJ	BRL -	BRL -	BRL -	BRL -	BRL -	BRL -
CSLL	BRL -	BRL -	BRL -	BRL -	BRL -	BRL -
Total Taxes	**-BRL 821,495.02**	**-BRL 821,495.02**	**-BRL 821,495.02**	**-BRL 821,495.02**	**-BRL 821,495.02**	**-BRL 843,995.02**
Total Expenditure + Total Taxes	**-BRL 12,455,714.08**	**-BRL 7,127,434.15**	**-BRL 7,127,434.15**	**-BRL 7,127,434.15**	**-BRL 7,127,434.15**	**-BRL 7,649,934.15**
Cash Flow	**-BRL 5,284,514.08**	**BRL 43,765.85**	**BRL 43,765.85**	**BRL 43,765.85**	**BRL 43,765.85**	**-BRL 328,734.15**

Table 7 - Cash flows for the first six years of the enterprise on the presumed profit regime.

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Gross Revenue	BRL 7,171,200.00	BRL 7,171,200.00	BRL 7,171,200.00	BRL 7,171,200.00	BRL 7,171,200.00	BRL 7,171,200.00
Selling of Equipment	BRL -	BRL -	BRL -	BRL -	BRL -	BRL 150,000.00
Equipment Sales Tax	BRL -	BRL -	BRL -	BRL -	BRL -	-BRL 22,500.00
Total Revenue	**BRL 7,171,200.00**	**BRL 7,171,200.00**	**BRL 7,171,200.00**	**BRL 7,171,200.00**	**BRL 7,171,200.00**	**BRL 7,321,200.00**
CAPEX (Miscellaneous + Plant Installation Costs)	-BRL 200,000.00	BRL -	BRL -	BRL -	BRL -	BRL -
Mining OPEX	-BRL 2,076,044.58	-BRL 2,076,044.58	-BRL 2,076,044.58	-BRL 2,076,044.58	-BRL 2,076,044.58	-BRL 2,076,044.58
Processing OPEX	-BRL 794,429.26	-BRL 794,429.26	-BRL 794,429.26	-BRL 794,429.26	-BRL 794,429.26	-BRL 794,429.26
General and Administrative OPEX	-BRL 2,462,685.68	-BRL 2,462,685.68	-BRL 2,462,685.68	-BRL 2,462,685.68	-BRL 2,462,685.68	-BRL 2,462,685.68
Purchase of Equipment	-BRL 6,238,350.00	BRL -	BRL -	BRL -	BRL -	-BRL 500,000.00
Stripping	-BRL 109,385.48	-BRL 109,385.48	-BRL 109,385.48	-BRL 109,385.48	-BRL 109,385.48	-BRL 109,385.48
Leasing	-BRL 300,000.00	-BRL 300,000.00	-BRL 300,000.00	-BRL 300,000.00	-BRL 300,000.00	-BRL 300,000.00
Working Capital	BRL 1,110,070.07	BRL -	BRL -	BRL -	BRL -	BRL -
Freight	-BRL 917,875.40	-BRL 917,875.40	-BRL 917,875.40	-BRL 917,875.40	-BRL 917,875.40	-BRL 917,875.40
Offsets	BRL -	BRL -	BRL -	BRL -	BRL -	BRL -
Total Expenditure	**-BRL 11,988,700.34**	**-BRL 6,660,420.40**	**-BRL 6,660,420.40**	**-BRL 6,660,420.40**	**-BRL 6,660,420.40**	**-BRL 7,160,420.40**
Depreciation	BRL -	BRL -	BRL -	BRL -	BRL -	BRL -
Expenses and Deductions	BRL -	BRL -	BRL -	BRL -	BRL -	BRL -
PIS/PASEP	-BRL 46,612.80	-BRL 46,612.80	-BRL 46,612.80	-BRL 46,612.80	-BRL 46,612.80	-BRL 46,612.80
COFINS	-BRL 215,136.00	-BRL 215,136.00	-BRL 215,136.00	-BRL 215,136.00	-BRL 215,136.00	-BRL 215,136.00
Previous year's compensable loss	BRL -	BRL -	BRL -	BRL -	BRL -	BRL -
Net profit before IRPJ and CSLL	BRL -	BRL -	BRL -	BRL -	BRL -	BRL -
Presumption of IRPJ (8%)	BRL 552,756.10	BRL 552,756.10	BRL 552,756.10	BRL 552,756.10	BRL 552,756.10	BRL 552,756.10
Presumption of CSLL (12%)	BRL 829,134.14	BRL 829,134.14	BRL 829,134.14	BRL 829,134.14	BRL 829,134.14	BRL 829,134.14
ICMS PE	-BRL 322,704.00	-BRL 322,704.00	-BRL 322,704.00	-BRL 322,704.00	-BRL 322,704.00	-BRL 322,704.00
CFEM	-BRL 71,712.00	-BRL 71,712.00	-BRL 71,712.00	-BRL 71,712.00	-BRL 71,712.00	-BRL 71,712.00
IRPJ	-BRL 82,913.41	-BRL 82,913.41	-BRL 82,913.41	-BRL 82,913.41	-BRL 82,913.41	-BRL 82,913.41
Additional 10% on IRPJ	-BRL 31,275.61	-BRL 31,275.61	-BRL 31,275.61	-BRL 31,275.61	-BRL 31,275.61	-BRL 31,275.61
CSLL	-BRL 74,622.07	-BRL 74,622.07	-BRL 74,622.07	-BRL 74,622.07	-BRL 74,622.07	-BRL 74,622.07
Total Taxes	**-BRL 844,975.90**	**-BRL 844,975.90**	**-BRL 844,975.90**	**-BRL 844,975.90**	**-BRL 844,975.90**	**-BRL 867,475.90**
Total Expenditure + Total Taxes	**-BRL 12,833,676.23**	**-BRL 7,505,396.30**	**-BRL 7,505,396.30**	**-BRL 7,505,396.30**	**-BRL 7,505,396.30**	**-BRL 8,027,896.30**
Cash Flow	**-BRL 5,662,476.23**	**-BRL 334,196.30**	**-BRL 334,196.30**	**-BRL 334,196.30**	**-BRL 334,196.30**	**-BRL 706,696.30**

3.2 Probabilistic economic assessment

As aforementioned in the Methodology section, we initially ran a set of 100,000 Monte Carlo simulations sampling inputs from the six statistical distributions presented in Figure 1 and considering both taxation regimes. In these simulations, we identified that the probability of the NPV (the output) being greater than zero was 57.10% and 47.86% for scenarios taxed by the real and presumed profit regimes, respectively. These results served as input for a sensitivity analysis, in which we verified the preponderance of the monthly production rate (m³) on the NPV of the project in relation to the other variables (around 87%), which is why another risk analysis was carried out through a new set of Monte Carlo simulations, thus considering only this variable. Figure 2 shows the percentage of explained variation of the sensitivity analysis on the project's NPV when the real and presumed profit regimes were chosen, respectively, highlighting the importance of the monthly production rate (m³) variable for this study.

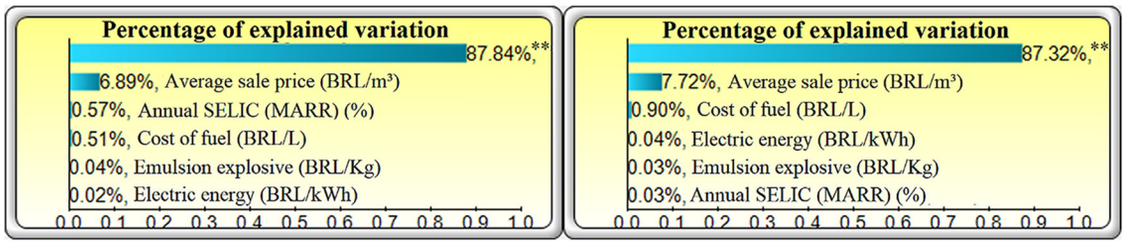

Figure 2 - Percentage of explained variation of variables in the sensitivity analysis, obtained through Monte Carlo simulations considering NPV as output. ** Monthly production rate (m³).

This time, considering only the monthly production rate as input and NPV and IRR as output, we generated a new set of 100,000 Monte Carlo simulations, whose histograms and risk analyses are shown in Figures 3 and 4 for the real and presumed profit regimes, respectively. In the images, the NPV histograms present null and deterministic NPVs as reference (cyan bar), while the IRR histograms present the SELIC rate adopted during the preparation of this study and the TMA as reference.

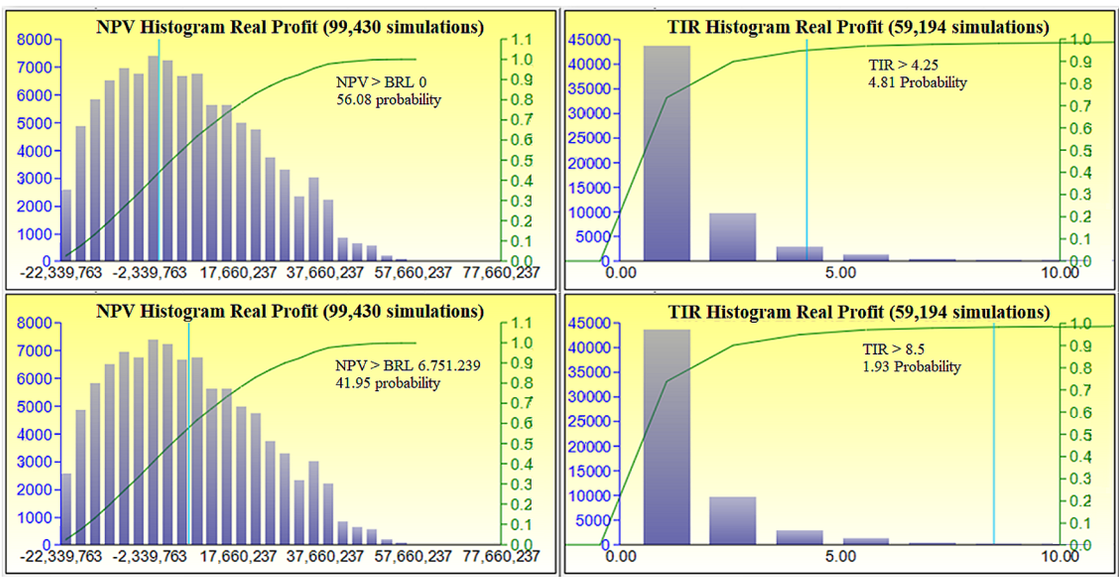

Figure 3 - Risk analysis of NPV and IRR histograms from the perspective of real profit regime.

Given the constraints imposed, the probability of having an NPV greater than zero in the project by the real and presumed profit regimes is 56.08% and 46.54%, respectively, while the probability of the IRR being greater than the SELIC rate is 4.81% and 3.23%, respectively. On the other hand, the probability of having an NPV greater than the deterministic NPV when considering the real and presumed profit modalities is 41.95% and 25.88%, respectively, while the probability of the IRR being greater than the TMA (8.5%) is 1.93% and 1.33%, respectively. In view of these results, regardless of the tax regime adopted, we advise against the immediate investment in this enterprise, since the most likely (deterministic) scenario presents a loss and the stochastic scenario indicates that there are probabilities around 50% of the project presenting some profit. Moreover, the chances of reaching the desired profit are even lower, and the probability that the IRR is greater than the inflation index when it is less than 5%.

When comparing the economic returns provided by the different taxation regimes from the perspective of the production rate, we can verify that the real profit modality presents superior NPVs regardless of the assumed monthly production rate, as shown in Figure 5. This is mainly due to the fact that it is a non-cumulative system, in which credits and expenses are more fairly compensated, in addition to allowing the discounting of previous losses and the collection of the IRPJ when there actually is a profit. Depending on the business model and its industrial activities, whose taxation criteria are different from those mentioned in this study, it is possible that

there is superiority of the presumed profit regime to the detriment of the real profit; in this quarry mining sector, however, taxation under the presumed profit regime is unfavorable in all circumstances evaluated here.

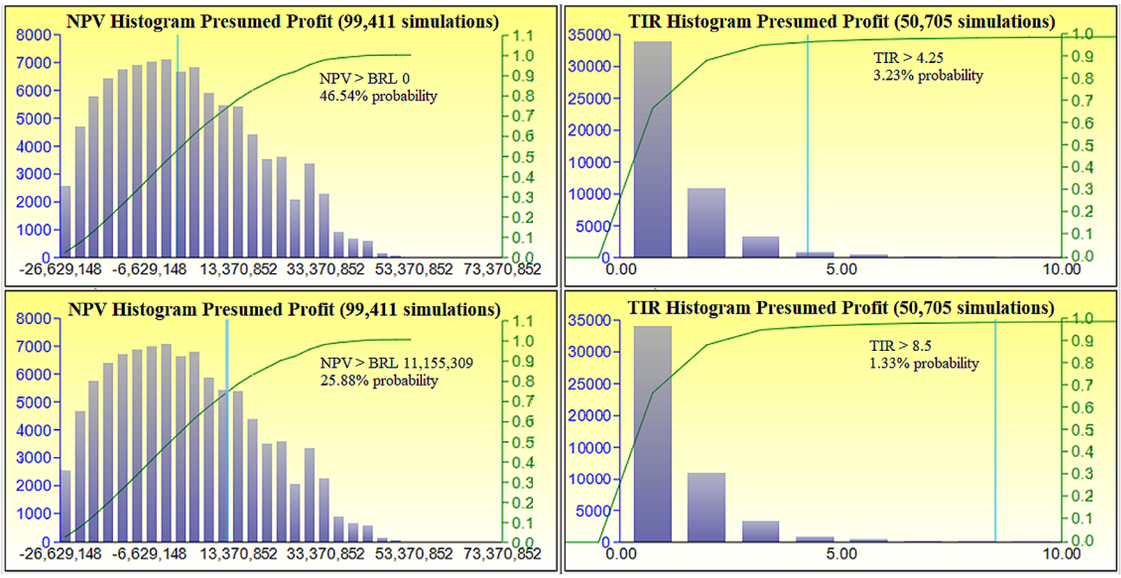

Figure 4 - Risk analysis of NPV and IRR histograms from the perspective of presumed profit regime.

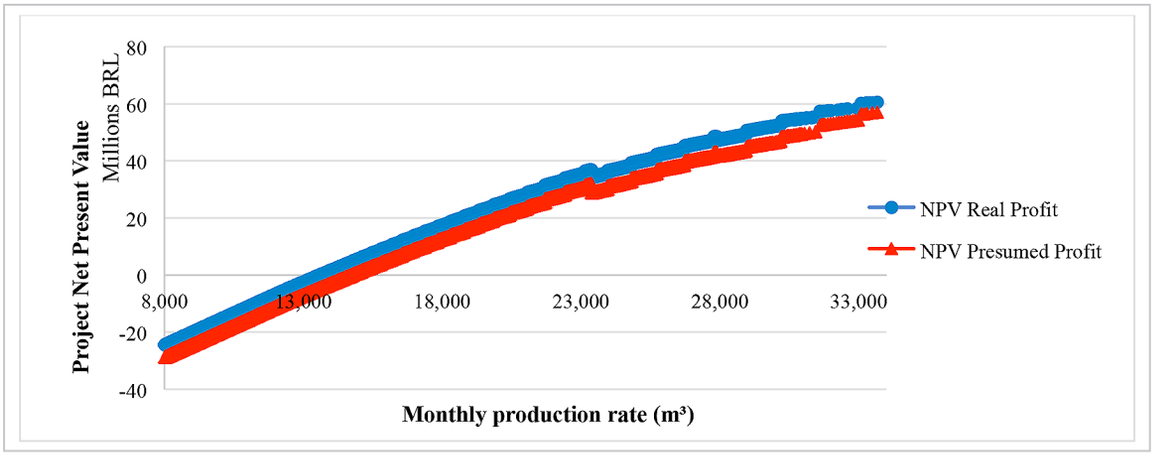

Figure 5 - Performance of the project's NPV in the real and presumed profit regimes in the face of different production rate possibilities.

4. Conclusion

This study aimed to carry out deterministic and probabilistic economic feasibility assessment at a quarry located in Pernambuco, Brazil, determining which tax model would be the most appropriate between real and presumed profit and whether it would be advisable to resume activities in the enterprise, currently interrupted. When carrying out the deterministic assessment for both considered tax regimes, we achieved negative NPVs, which advises against the resumption of operations. Nevertheless, as deterministic assessment alone is not capable of identifying and quantifying project risks, we also performed a probabilistic assessment through Monte Carlo simulations and a sensitivity analysis to indicate the most impacting variables on the project's NPV and carry out a risk analysis. We found in the sensitivity analysis that among the six variables chosen as the most important, the production rate explains about 87% of the output NPV variation, which is why this variable was chosen to remain as a statistical distribution input in the final set of Monte Carlo simulations.

Hence, considering both NPV and IRR as output, we verified in the risk analysis that, for the assumed constraints, there is a probability of obtaining some profit (NPV being higher than zero) of 56.08% and 46.54% for the real and presumed profit regimes, respectively. Moreover, regardless of the production rate considered, we verified that taxation under the real profit regime had a higher economic return (NPV) than taxation under presumed profit. Finally, considering a probability of approximately 50% of occurrence of a positive NPV and as it is almost impossible to achieve an IRR higher than the SELIC rate adopted in this study for all scenarios evaluated, investment in other economic projects should be considered as long as the economic situation remains within the spectrum of possibilities evaluated.

In addition, historically, the adequacy of the sale price of aggregates in Pernambuco to increase inputs was already inadequate even before the COVID-19 pandemic, since it depends on a local market strongly influenced by civil construction, which has slowed down significantly in recent years. After the pandemic, however, there was a devaluation of the Brazilian economy, which culminated in a rise in

interest rates (SELIC rate) of more than 200% in approximately one year, as well as a decrease in the purchasing power of Brazilians regarding essential commodities for mining, such as steel, nitrate (explosive) and fuels. Therefore, even if we have achieved the objective of identifying the most advantageous tax regime for the enterprise, an immediate investment would be strongly discouraged, as the scenario of Brazilian economic instability tends to make the risk analysis even more unfavorable.

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