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Monte Carlo Simulation in the Assessment of Economic-financial Uncertainties of a Manufacturing Industry

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Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

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ABSTRACT

For accurate decisions in capital investments assessments into industrial projects, it is recommended to consider the uncertainties intrinsic to the capital budget. In this way, our objective was to assess the economic and financial viability of a manufacturing industry, based on the uncertainty of the elements that make up the cash flow of this industry that performs the sawing of *Pinus* sp. logs, located in São Paulo State, Brazil. As a premise, the deterministic discounted cash flow was constructed; therefore, probability distributions were assigned to the input variables of the mathematical model, for the stochastic values of the quantitative methods, traditionally employed in investment analysis, through Monte Carlo simulation. The results showed that the investment project is economically viable; in addition, it presented an economic-financial risk that can be considered low.

Keywords: Stochastic model; cash flow; Pinus; net present value.

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1. INTRODUCTION

The assessment of investments involves the use of techniques and criteria for analysis that compares the costs and revenues inherent to the projects, in order to verify whether they should be implemented or not [1]. In the strict sense, the economic-financial analysis of a project estimates the impact that its implementation will have on the current situation of the company, project or market. For this, a set of techniques that seek to establish viability parameters is often used in the assessment of investment projects [2].

In principle, the analysis of investments in projects consists of a special type of budget. Its differential occurs because it considers the time factor explicitly, by including the variation in the value of money over time, in the formation of the monetary flows involved in the project, or cash flow [3].

Considering that, naturally, the capital investment projects have associated uncertainties, it is essential to adopt stochastic processes that can be approached with Monte Carlo simulation method, describing the behavior of factors that could compromise the economic and financial viability of these projects.

Monte Carlo method is a stochastic simulation technique that iteratively assesses a deterministic model, which uses random variables as inputs since this method can be used to value an investment proposal and to better understand and manage risks. The combination of input variables encompasses the set of scenarios and risks to which the investment can be exposed [4].

In addition, Monte Carlo simulation is considered one of the most reliable methods of uncertainty assessment because it does not make assumptions about the linear behavior of the model. The method has been widely used in probability and statistical analysis due to the simple and high precision process, besides describing the uncertainty propagation of input and output variables [5]. For this, it requires the generation of random values for the model input, where the model variables have a known interval [6].

Monte Carlo method generates artificial values of a probabilistic variable by using a random uniformly distributed number generator in the [0.1] interval and also by using the cumulative distribution function associated with this stochastic variable, besides being relatively easy to perform and provides important information regarding the risks of investment projects [7].

In this way, Monte Carlo simulation allows obtaining the probability distribution of the output variable by means of the arrangement of the distributions attributed to the input variables; so, to those considered as more relevant to the mathematical model. This condition allows the decision making based on intervals and stochastic values, which, therefore, admit the measurement of the risk of an investment project.

In this sense, the objective was to assess the economic-financial viability of a manufacturing industry based on the uncertainty of the elements that make up the cash flow, through Monte Carlo simulation, to measure the intrinsic risk to the investment project.

2. MATERIALS AND METHODS

2.1 Business Model

The study was carried out in a manufacturing industry, located in São Paulo State, Brazil, which performs the sawing of *Pinus* sp. logs, with diameters from 14 cm to 30 cm, and a maximum length of 2.5 m, for the manufacture of boards for packing, with emphasis on value aggregation and marketing of horticultural packaging.

2.2 Economic-financial Analysis

Monetary values were expressed in US dollars since they are international parameters of the financial market [8]. Thus, the exchange rate of the foreign currency made available by the Central Bank of Brazil [9] at the sale price was used, measured in units and fractions of the national currency, which was 3.3207 BRL on June 13, 2017.

Discounted cash flow (DCF) is the traditional methodology used to assess capital investments in projects. Therefore, the investment project was assessed based on the DCF designed for a period of 10 years, which is considered as reliable for the forecast of the cash flows of the investment alternative, according Penman and Sougiannis [10] this horizon is considering a perfect foresight approach.

However, the net present value of the manufacturing industry was calculated from the terminal value, i.e., after the residual value of the projection period, given that the DCF was presented as infinity. Thus, it was recognized that, after the end of the projected period, cash flow increased at a rate of 1.5% [11], equivalent to the growth rate of the manufacturing sector for the period 2016-2025.

In order to assign a value to these cash flows, a discount rate calculated using the capital asset pricing model (CAPM) was used to relate the required return of an investment to its systematic risk [12]. In addition, the CAPM was considered as the attractiveness rate required for the project, that is, for accepting or not the investment project (Eq. 1).

$$K = R_f + \beta(R_m - R_F) + \alpha_{BR} \tag{1}$$

where:

K is the rate adjusted discount rate risk;

R_f is the risk free rate (ten year T-Bills rates);

β is the systematic risk of the forest products industry;

R_m is the expected return of the market;

$(k_m - k_{rf})$ is the risk premium;

α_{BR} is the country risk premium.

2.2.1 Quantitative methods of investment analysis

The net present value (NPV) was adopted as the main method of analysis of the investment project since it is explicitly used in the assessment of the economic-financial viability of investment projects (Eq. 2).

$$NPV = \sum_{j=1}^{n} \frac{CF_j}{(1+i)^j} - I_0 \tag{2}$$

where:

NPV is the net present value (USD);

n is the duration of the investment project;

i is the interest rate;

I_0 is the investment processed at time zero (initial).

The profitability of the investment project was analyzed based on the modified internal rate of return (MIRR), considering that positive cash flows will be reinvested to the cost of capital (Eq. 3).

$$MIRR = \left[\frac{\sum_{j=1}^{n} REV\ (1+i)^{n-j}}{\sum_{j=1}^{n} \frac{|C_j|}{(1+i)^j}}\right]^{\frac{1}{n}} - 1 \tag{3}$$

where:

$MIRR$ is the modified internal rate of return (%);

REV is the revenue (positive net value, in each period "j" of cash flow);

C_j is the costs (negative net value, in each period "j" of cash flow).

In this perspective, the historical series of yields credited to the Total Savings Account between January 2, 2006 and July 10, 2017 were used as the reinvestment rate, and the economic-financial time series referring to the rate of the Special Clearance and Escrow System, observed between January 2006 and May 2017, were weighted as the financing rate (fundraising), both series made available by the Central Bank of Brazil [13].

In addition, in order to demonstrate the project's profitability, that is, the present value per dollar of initial cost, the profitability index (PI) was used according to Eq. (4).

$$PI = \frac{\sum_{j=1}^{n} \frac{CF_j}{(1+i)^j}}{I_0} \tag{4}$$

2.3 Risk Analysis

To project the reinvestment and financing rates of cash flows, the time series data were decomposed through Trend. Thus, the autoregressive integrated moving averages – ARIMA process (p.d.q.) was adopted due to the best fit to the data, besides the statistical model selected by Bayesian Information Criterion (BIC).

The modeling of the risk analysis was based on the distribution of probabilities for each input variable of the model and, therefore, considered stochastic variables as a result of the assigned triangular parameterization (Table 1) for Monte Carlo simulation.

The sensitivity analysis was based on the correlation coefficients between the NPV and the stochastic variables, and it allowed to assess which of these variables most influenced the values of the interest variable. Thus, simulations, i.e., the descriptive statistics of the data and the Spearman correlation coefficient used to verify

Table 1. Stochastic variables in Monte Carlo simulation model

Variable	Unit.	Minimum	Most likely	Maximum
CAPEX	USD	732,767.94	862,079.93	991,391.92
Variable cost	USD/ p.a.	850,912.42	1,001,073.44	1,151,234.45
Variable expenses	USD/ p.a.	161,799.90	190,352.82	218,905.74
Fixed cost	USD/ p.a.	31,685.28	37,276.80	42,868.32
Administrative costs	USD/ p.a.	4,368.88	5,139.86	5,910.84
Packaging	un./ p.a.	1,767,779	2,079,741	2,391,702
Packaging Price	USD/un.	0.62	0.73	0.84
Chip	m^3/ p.a.	10,327.50	12,150.00	13,972.50
Chip price	USD/m^3	6.56	7.72	8.88
Sawdust	m^3/ p.a.	3,966.95	4,667.00	5,367.05
Sawdust price	USD/m^3	3.30	3.88	4.46

the interrelationship of the input variables, were obtained through the software @Risk Copyright© 2016 Palisade Corporation [14], with the generation of 100,000 pseudorandom numbers simulated by Monte Carlo method. The random number generator used in the simulation process was the Mersenne Twister, with the same initial data.

3. RESULTS AND DISCUSSION

The capital asset pricing model (CAPM) is one commonly used model for determining the size of project risk as a function of the market risk premium [15]. So, based on the 2.14% risk-free interest rate issued by the US Treasury Department for the 10-year period, of the weighted coefficient β_e 1.12 for forest products industries, the market risk premium of 10,50% and Brazil risk premium of 4.90%, it was possible to determine the return on risk-free assets, that is, the cost of equity of 16.41%, which made it possible to bring all future cash flows to the present date, taking into account the risk of the project.

Thus, from the probabilistic cash flow, a probability distribution was obtained for the NPV output variable, concomitantly constructing a 90% confidence interval that resulted in (1,462,130 USD; 1,473,549 USD), which expresses the estimate accuracy of the NPV average value, which is not included in the point estimate. In addition, it was possible to measure that there is a 9.3% probability of NPV being less than zero; therefore, for this scenario, revenues will be lower than production costs.

The sensitivity analysis allows determining the impact and the relevance of each weighted variable in the stochastic model. Thus, the variables that have a positive correlation with the NPV (Fig. 1) are the packaging and the respective price, both with Spearman correlation coefficients higher than 0.6, and the magnitude of this coefficient can be interpreted as moderate [16]; therefore, the greater the quantity of packaging marketed, the higher the NPV, and this condition also applies to the price of this packaging.

However, variable cost resulted in a negative (moderate) correlation coefficient, followed by variable expenses and CAPEX, which have a low correlation with NPV. Accordingly, these variables are inversely proportional to the NPV, then they should be monitored so that they do not increase the economic-financial risk of the capital investment project.

From the perspective of BIC model selection criterion, it was observed that the best probability distribution, which fit the data generated for the NPV, was the Normal distribution with mean of 1,467,840 USD and standard deviation of 1,097,584 USD (Fig. 2). Even though it is a symmetrical distribution, we noticed a high dispersion for the values of this quantitative method of investment analysis.

The modified internal rate of return, although not perfect, at least allows users to establish more realistic reinvestment rates and, therefore, to calculate a true annual equivalent income [17]. Thus, the modal value of MIRR was 23.86%, consequently, higher than the cost of equity. Due to the capital investment project being independent, this can be accepted based only on this criterion, mainly because the probability of 74.82% of MIRR is superior to CAPM. It was observed that MIRR has asymmetric distribution, whereas CAPM has symmetrical distribution with little dispersion (Fig. 3); as well as the mean value for MIRR was 19.86%, also superior to CAPM.

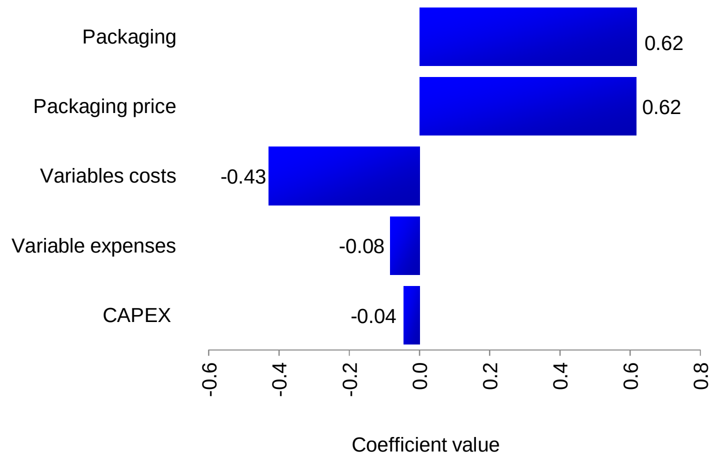

Fig. 1. Spearman order correlation coefficients of the five variables that most influence the NPV of the investment project

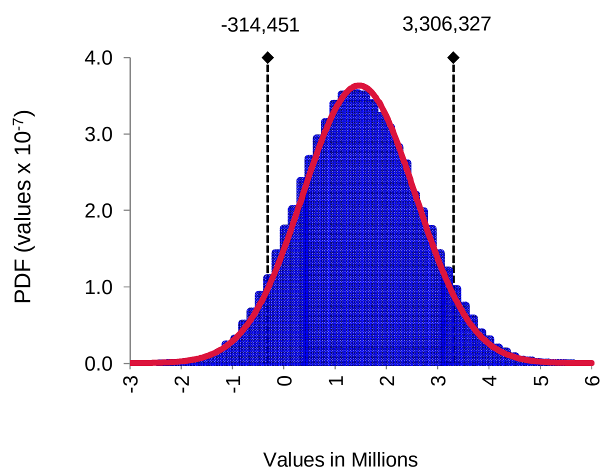

Fig. 2. Probability density function (PDF) of the NPV of the investment project

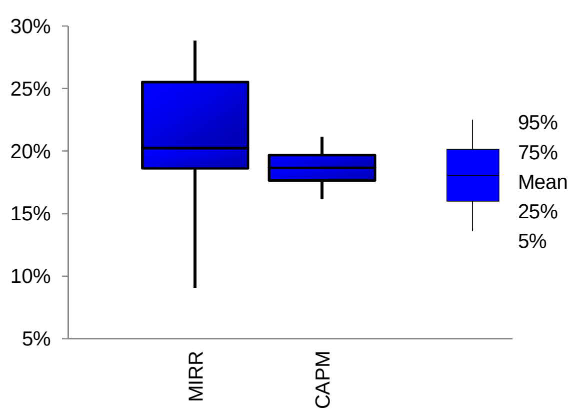

Fig. 3. Box-plot for MIRR and CAPM for the analysis of the investment project

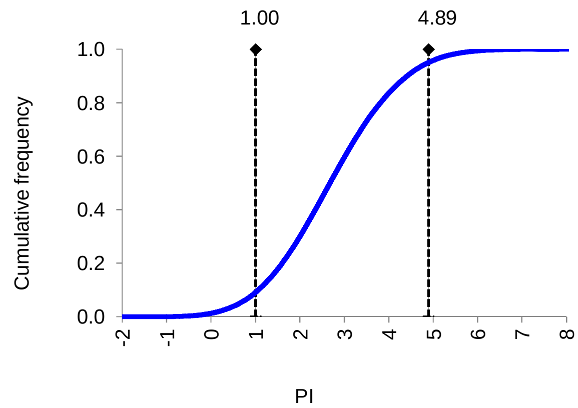

Fig. 4. Cumulative frequency of PI for the analysis of the investment project

Regarding the profitability index, a quantitative measure that establishes the ratio between the present value of the expected cash flows and CAPEX resulted in an average value of 2.71, and the probability of this index is less than 1, that is, the percentage the investment project cause financial loss to the investor is 9.1. When analyzing the 95th percentile, it can be seen (above Fig. 4) that 95% of the stochastic results of the PI were smaller than 4.89; in addition, 85.9% remained between 1.00 and 4.89.

4. CONCLUSIONS

The economic-financial assessment through Monte Carlo simulation allowed the construction of the probability curves to measure the risk, as well as predictions given by the stochastic values of the quantitative methods of investment analysis.

The probability density function of the net present value indicated that the possibility of net present value being positive is 89.9%, which corroborates the economic-financial viability of the investment project for wood sawing.

The modified internal rate of return is 7.45% higher than the explicit rate of the investment project.

The profitability index has shown that there will be financial resources available after payment of all costs, expenses, charges and depreciation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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