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MULTIVARIATE ANALYSIS IN FORMULATION OF THE BENEFIT-COST INDEX RELATED TO THE SUGARCANE PRODUCTION SYSTEM IN THE QUIRINOPOLIS MUNICIPALITY PRODUCTIVE CENTER, GOIAS, BRAZIL

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ABSTRACT

Food and bioenergy agriculture are growing demands of the global population. The problem of rural production facilities resides in gross revenue and not in issues related to production scale, since the price is determined by the market. The performance measure indicators, whether financial or not, have helped managers to focus their actions on long-term perspectives of sustainable socioeconomic production in rural production facilities. It is proposed to validate an equation model composed of social and economic indicators as a parameter for monitoring the development of sugarcane production in agricultural production facilities by means of multivariate analysis techniques and to characterize the socioeconomic factors different profiles in rural production facilities studied. The methodological approach was quantitative, applying techniques of inferential statistics and multivariate analysis by test for normality, test of the Friedman hypothesis, Categorical Principal Components Analysis, adjustment of multiple linear regression model and profile segmentation. The statistical tests showed statistical significance ($P<0.05$), CATPCA presented 2 dimensions with Cronbach's alpha adequate and a linear regression model was adjusted with adequate R^2 of 0.90. The results by profile show that the IBCcane was the best of the smallholdings with 24.39 ha-1, (100% of the lessors). The IBCcane by establishments profile was: 424.39 (smallholding); 174.66 (small); 827.34 (medium); and 2,765.96 (large). The multivariate analysis determined the equation validity for the proposed indicators, it was proven that the smallholdings have the best benefit-cost index and the benefit-cost by profile showed that the large ones have a greater financial gain due to the productive scale.

Contribution/Originality: The main contribution of the article is the combination of multivariate analysis techniques CATPCA Summary Model Rotation and multiple linear regression in the validation of a two-dimensional equation model with the main socioeconomic variables that influence the benefit-cost index for the sugarcane production system.

1. INTRODUCTION

Recent studies have established premises in the international agricultural scenario, collaborating with evidence and fostering the need for further developmental practices (Igari *et al.*, 2009; René *et al.*, 2014; Rosolen *et al.*, 2015), since food and bioenergy production has attracted global attention due to the growing needs of the global population (Maroun and La Rovere, 2014; Medina and dos Santos, 2017). The new agricultural frontier requires a process that envisions crop diversity with optimal land use, as the productive areas that can be sustainably occupied are increasingly limited (Franks, 2014). Studies on agroindustrial chains demonstrate the concern in characterizing the agents of production chains and operational costs (Andia *et al.*, 2011).

Agricultural production systems have been the focus of research on performance measurement, demonstrating its importance for all agents of an agroindustrial chain and that the agricultural production facilities cannot establish its profit margin. The problem resides in the process of determining gross revenue and not in issues of scale of production, since the price is determined by the market (Andia *et al.*, 2011). The performance measurement indicators, whether financial or non-financial, have helped managers to focus their actions on long-term perspectives of sustainable socioeconomic production in rural production facilities, where the multivariate analysis become more relevant in the preparation and selection of the most influential factors in the results (Machado *et al.*, 2015). In this perspective, the use of indicators and rates for the assessment of sustainability has grown considerably in recent decades, including in the sugarcane production system, since it is an instrument that provides technical information in a synthetic manner, presenting the variables that best represent the desired objectives (Guimarães *et al.*, 2010). It is also important to highlight that the sugarcane production system, for obtaining results such as economic viability, has demonstrated, in specialized research, concerns with economic indicators and logistical factors, which involve problems related to distance and transportation time from the agricultural production facilities to the sugar energy agroindustry, due to the degradation of sugarcane and consequent economic loss (Gilio and De Moraes, 2016; Spera *et al.*, 2017).

The sugarcane production system has also been the focus of research regarding social indicators, since the perception of their influence on economic factors is feasible (Machado *et al.*, 2014; Machado *et al.*, 2015). In the scenario of agricultural expansion in Brazil, there has been a substitution of food crops and pastures by sugarcane plantations (Gilio and De Moraes, 2016). The city of Quirinópolis is part of this context and was consolidated with the production, in 2017, of 7,142,253 tons of sugarcane in a harvested area of 86,262 hectares, as the main sugarcane producing pole in Goiás and the second one in Brazil (IBGE – Instituto Brasileiro de Geografia e Estatística, 2018a) justifying studies that may contribute to the local socioeconomic development (Dzanja, 2018).

The expansion of sugarcane cultivation has caused an economic impact on the region (Spera *et al.*, 2017) and production efficiency, cost management and production systematization are essential factors for competitiveness and sustainability, in which the producer should be concerned whether the remuneration of his activity will be sufficient to cover the total costs (Vilela *et al.*, 2017). The article aims to validate an equation model composed of socioeconomic indicators as a parameter for monitoring the development of sugarcane production in agricultural establishments through multivariate analysis techniques, as well as characterize the socioeconomic factors of the different studied profiles.

2. LITERATURE REVIEW

Brazil is recognized as an exponent in world agricultural production, even with the agribusiness producer living with high interest rates, very high logistics costs, bureaucracy and other limiting factors. The sugarcane crop emerges in this scenario of strength of the agricultural business sector with very intense growth in recent years due to the need for renewable fuels driving the economy. The impacts of the expansion of sugarcane plantation for biofuels agribusiness, as well as economic benefits bring growing perception of social, environmental and land use problems to the regional community (Petrini *et al.*, 2016).

In the period of World War II and the average content of the mixture of ethanol in gasoline reached 40% in the Northeast of Brazil, due to the scarcity of oil. In 1966, a government rule came into force to encourage the use of up to 25% of ethanol supplies and soften variations in sugar prices (Hira and Oliveira, 2009). In the 1970s, it turned out that not wanting to depend on oil imports, the Brazilian government implemented the Proálcool program, which subsidized resources for infrastructure and technology for the production of large-scale sugarcane-based ethanol.

At the beginning of this century, issues such as high global sugar prices, policies for renewable energy in Brazil as in other countries, and the advent of bi-fuel vehicles (ethanol, gasoline or blended) in 2003 increased pressure for production in large scale sugar cane. Against this background, from 2003 to 2011, Brazil's National Bank for Economic and Social Development lent about $ 28 billion in financing projects to ethanol agro-industry owners. (Mendonça *et al.*, 2013). Milanez and Nyko (2014) assert that the sugarcane sector has recently been facing new challenges due to the financial crisis of the last decade, aggravated by the high indebtedness index that the segment has embarked on. Accumulated to this, bad harvests due to inadequate climate, structural increase of costs and consequently the reduction of profitability margin of agro-industries.

Crops in the Center-South region, Brazil and Goiás showed a growth trend in relation to the 2010/2011 crop until the 2014/2015 crop and subsequent slight decrease at national and regional level, except in Goiás. It is also demonstrated that the growth of Areas planted by crop has slowed in recent years (Milanez and Nyko, 2014). It is important to keep in mind that the sugarcane production system began in the city of Quirinópolis in 2005 with the first plantations of the crop due to the implementation of the São Francisco Plant agribusiness, currently SJC Bioenergy and later in 2008. Boa Vista Plant was inaugurated, now called New Frontier Bioenergy, in which they were responsible for changing the local socioeconomic paradigm.

Brazil has historically been characterized by high levels of concentration of capital as well as of rural property, and with the expansion of sugarcane cultivation through land lease agreements between farmers and the sugarcane agribusiness, there have been several impacts. mainly to smallholdings and small areas (Petrini *et al.*, 2017). Another issue that plagues small producers is issues related to representativeness vis-à-vis political channels, insufficient power to participate in policy management discussions in which they provide ways to influence public policies that could safeguard this public (Guanziroli *et al.*, 2013).

The expansion of productive sugarcane cultivation involves the fact that it is in competition with agricultural food production and its negative impacts on land use change (Dauvergne and Neville, 2010; Maroun and La Rovere, 2014). Studies indicate that sugarcane cultivation expands more often to pasture land than to agri-food crop land. Thus, pastures rather than crops are generally converted to sugarcane, with this effect livestock production in expanding regions has declined dramatically (Sparovek *et al.*, 2009; Novo *et al.*, 2010; Egeskog *et al.*, 2016).

Reflecting regarding the future management of the expansion of the sugarcane production system, it is essential to understand the current socioeconomic and environmental factors that shape this expansion of the crop. Sugarcane is a crop that fits best in regions with specific land biophysical characteristics such as rainfall reliability, fresh minimum temperatures, slope and soil type (Scarpari and Beauclair, 2004; Jasinski *et al.*, 2005) , occurring similarly in the State of Goiás (Trindade, 2015).

Socioeconomic issues in implantation regions have been favorable, since they show improvements in the averages of these indicators, also verifying that the migratory flow for sugarcane related work has been absorbed through the creation of formal jobs expressed by the Employment and Income variable of the FIRJAN Municipal Development Index Oliveira *et al.* (2014).

The farmer has leased his land or become a sugarcane producer depending on his economic and family situation and may want to sell it to the sugarcane agribusiness. Farmers who convert their land to sugarcane through lease or production do not return to pasture or cropland due to the high cost of converting sugarcane to another crop and in relation to yields often higher than sugarcane production. provides sugar to the landowner (Egeskog *et al.*, 2016). Pasture cultivation is often considered a low-income activity and specifically in this situation the investment that sugarcane cultivation makes in the soil increases the future prospect of land rent value (Sparovek *et al.*, 2007).

In regions where synergistic infrastructure and logistics are available, economies of scale reduce the cost of production, and this influences farmers who are less likely to sell, rent or convert pasture or soybeans to sugarcane (Sparovek *et al.*, 2007; Nagavarapu, 2010; Gilio and De Moraes, 2016; Spera *et al.*, 2017). If they are surrounded by other soybean farmers or farmers, or infrastructure that supports intensive soybean production or pasture, crop exchange is less effective, a fact found in São Paulo with the sugarcane sector (Goldemberg, 2007) and with penetrating soy and cattle sectors across the Amazon and Cerrado (Garrett *et al.*, 2013).

The association and organization factor can also be identified as an influencing factor in the socioeconomic compound for farmers. Spera *et al.* (2017) report that strong *lobbying* from livestock farmers and grain growers can make it difficult to expand sugarcane in a region. In 2006, in the municipality of Rio Verde, rural unions and grain processing companies came together to pass a law prohibiting the expansion of sugarcane in the region, even though later considered unconstitutional demonstrates the strength of the articulation of producers and *stakeholders*.

Many studies have been published seeking to understand the economic, social and environmental impacts and especially pointing the mechanisms for the sustainability of the sugarcane industry. Clearly, most studies focus on issues of economic and environmental sustainability, but social issues still need to be investigated. There are several scientific researches that suggest benefits for the population of the sugarcane industry expansion regions in Brazil, citing mainly the generation of jobs and income (Mangoyana *et al.*, 2013; Ribeiro, 2013).

Ribeiro (2013) indicates that regional development from sugar cane can increase levels of social vulnerability, also influencing the generation of processes of social change, and the responses associated with these transformations, when identifiable, may be positive or negative. The federal and state governments have developed regulatory frameworks aimed at reducing the social and environmental impacts of the sugarcane production system, as well as proposing zoning laws, environmental regulations and fostering voluntary workers rights agreements. Duarte *et al.* (2013).

3. METHODOLOGY

For the socioeconomic analysis of agricultural production facilities, it was necessary to statistically validate variables and establish a list of rates aiming to measure the influence of the sugarcane production system on local rural properties. The field research was conducted from June 2018 to February 2019, with the owners. The rural production facilities studied are located in 21 micro-regions of Quirinópolis, geographically positioned by the coordinates: 18°26'52" South latitude and 50°27'07" West longitude, average altitude of 541 meters, located in the southwest region of Goiás and in the southern region of Goiás (IBGE, 2018b).

3.1. Sampling Procedures

The research universe includes the 67 existing sugarcane producing agricultural production facilities (IBGE, 2018a) parameter for sample calculation. The sample adopted a 95% confidence level for data collection and analysis, with a margin of error of 5%, resulting in a sample of 58 agricultural production facilities (Santos, 2016). The research is quantitative, with fieldwork adopting the survey method (Lund, 2012).

In the data collection, printed questionnaires were used for the interviews, contemplating the research variables Table 1. The data collection questionnaire was divided into two different sections: the first section collected general data on the profiles of owners and agricultural production facilities, and the second one collected conceptions about research variables from the perspective of the social and economic dimensions. In the first phase of the research, the pre-test of the questionnaire was applied in the field to verify inadequacies, inconsistencies and errors in the questions, which allowed correcting ambiguities and other identified non-conformities. The application of the instrument includes the micro-regions of the city in the following way:

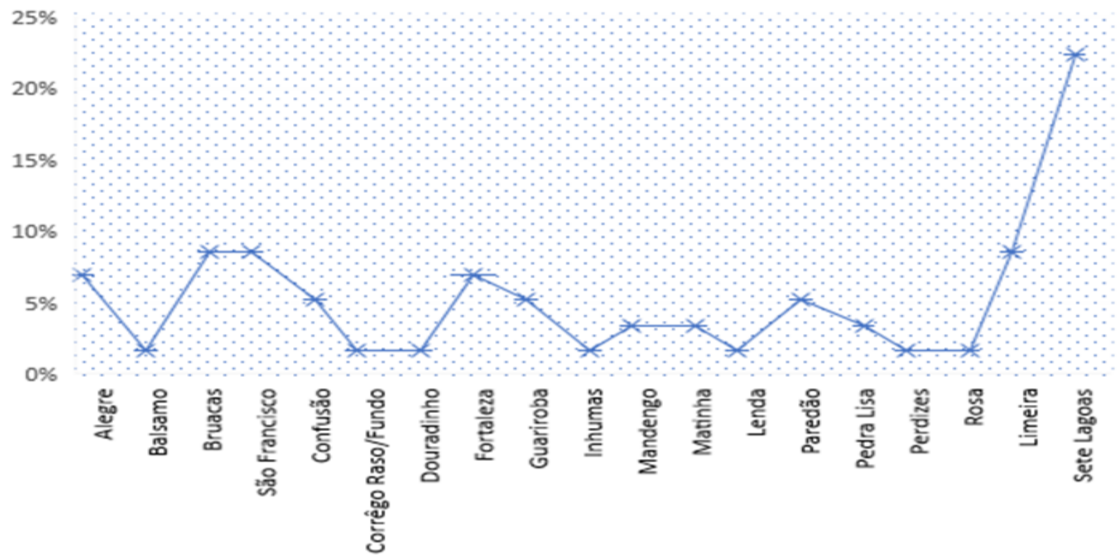

Figure-1. Frequency and distribution graph of data collection in the microregions in the rural area of Quirinópolis - GO, 2018/2019.

The field research was conducted in the rural area of the municipality of Quirinópolis - GO, 2018/2019. Among the twenty-one micro-regions in rural areas, seventeen have farms with productive activity related to sugarcane. The micro-regions of Sete Lagoas, Limeira, São Francisco and Bruaca are the ones that stand out the most in terms of frequency in this productive system Figure 1.

3.2. Research Procedures

The steps adopted for the development of the research were: (I) planning and preparation of questionnaires; (II) logistic study and data collection in agricultural production facilities; (III) data tabulation; (IV) preliminary analysis of the data, evaluation of the adequacy of the sample and statistical measures; (V) application of Kolmogorov-Smirnov test for normality, Friedman's ANOVA and CATPCA; (VI) construction of the multiple linear regression model; and (VII) data exploration through the profile of socioeconomic indicators (Lund, 2012). IBM SPSS Statistics 24.0.0.0® and Microsoft Office Excel® applications were used to explore the data and perform multivariate analyses to meet the research objectives.

3.3. Measures, Covariates and Statistical Analysis

Some statistical tests were necessary to achieve the objectives, and it was also necessary to validate the variables by means of statistical techniques, considering 1 response variable and 17 predictor variables for the formulation of the equation model Table 1.

Usual abbreviations of variables: Index Benefit Cost by cane (IBCcane)**;** Index Associative (IA); Index Business Attractiveness (IBA); Index Exodus by cane (IEcane); Index Succession Capacity (ISC) and Total Operating Costs by cane (TOCcane).

In order to perform the statistical selection with data consistency, a multivariate analysis was implemented with the Categorical Principal Components Analysis method to group and reduce the 17 predictor variables into two categorical dimensions, in which 15 variables were validated. The Categorical Principal Components Analysis is an exploratory analysis technique for multivariate data that transforms correlated variables into a smaller group of independent variables, being used as indicators that summarize the information available in the original variables. Then, the Kolmogorov-Smirnov test for normality and Friedman's ANOVA test (a non-parametric alternative) were applied, in which the data ranks were used instead of their raw values to calculate the test statistics. In this test, multiple comparisons are made to verify if the null hypothesis, H_0 was rejected. After the statistical tests, only 12 variables were validated for multivariate analysis.

Table-1. List of variables considered for the validation tests and multivariate analysis.

Variable	Equation	Description
Index Benefit Cost by cane	$\overline{Z} = \frac{\frac{\sum_{i=1}^{N} \overline{X_i}}{n}}{\frac{\sum_{i=1}^{N} \overline{y_i}}{n}}$	The Benefit / Cost Ratio is the ratio of how much you expect to earn for each unit of capital invested (Treasy, 2018). In this study, it was adapted to the ratio of how much the agricultural establishments of the sugarcane production system earn for each unit of capital costed, that is, the ratio between the average remuneration flow (x) earned from the business. and the total operating costs (y) required for production. The analysis of the $(IBC_{cana}$, for business valuation, is analogous to that of NPV (Net present value) and IBC (Brazilian Institute of Coaching) for investment. If $IBC_{cane} > 1$, acceptable; if $IBC_{cane} < 1$, rejectable.
Previous Activity	$\overline{R} = \frac{PA}{N}$	Represented by the ratio of the incidence of agricultural activities prior to the implementation of sugarcane cultivation. It collaborates for the understanding of land use change.
Age	$\overline{X} = \frac{\sum_{i=1}^{N} \overline{X_i}}{N}$	Represented by the average of the age groups of the owners of agricultural production facilities of sugarcane. It collaborates for the understanding of the sociodemographic profile.
Agroindustry Distance	$\overline{X} = \frac{\sum_{i=1}^{N} \overline{X_i}}{N}$	Measured by the average distances between rural properties and the sugar-alcohol agroindustry, this logistical factor impacts the analysis of potential costs and remuneration. The average distance in this research uses the kilometer (km).
Associate	$A = \frac{\text{Nº Production Facility}}{\text{Total of Production Facilities}}$	Represented by the proportion of agricultural production facilities that are associated or not with any entity representing the rural sector and the total.
Identification	-	It expresses the group of characteristics of the rural production facilities that individualizes it.
Index Associativism	$\overline{X} = \frac{\sum_{i=1}^{N} \overline{X_i}}{N}$	Measured by the average obtained among the variables, regarding the perception of the benefits of a representative entity, through the evaluation of the degree of the variables: representativeness (x_1), negotiation (x_2) and conflict resolution (x_3). The likert scale was used to score values from 0 to 5.
Index Business Attractiveness	$\overline{X} = \frac{\sum_{i=1}^{N} \overline{X_i}}{N}$	Expressiveness of the main reasons for the change of production system in the land. This rate figure is calculated using the following indicators: Liquidity, guaranteed income, profitability, production system, health status, need for investment and land valuation. The likert scale was used to score values from 0 to 5.
Index Exodus by cane	$IE_{cane} = \frac{R_{previous} - R_{after}}{R_{previous}}$	Measured by the number of people who emigrated from agricultural properties after the change in the productive system, verifying the location of the rural exodus. The index uses a linear rating scale that includes negative and positive numbers (scores).
Index Succession Capacity	$\overline{X} = \frac{\sum_{i=1}^{N} \overline{X_i}}{N}$	Measured by the arithmetic average obtained in the evaluation of the variables: vocation (x_1), practical skills (x_2) and technical training (x_3) regarding successors in the management of agricultural production facilities. It uses Likert evaluation scale including numbers from 1 to 5.
Microregion	-	It refers to the location of the rural production facility in the micro-regions of Quirinópolis.
Remuneration	-	The compensation for the sugarcane production activity was calculated based on the ton of sugarcane produced and converted at the Total Recoverable Sugar (ATR or *Açúcar Total Recuperável*) quotation on July 10, 2018 (CONSECANA, 2018) and the currency conversion (real to U.S. dollar) was effective on the same date. The remuneration of agricultural production facilities was calculated over the production area to obtain the value of remuneration per hectare (US$/ha).

Schooling	$\bar{X} = \frac{\sum_{i=1}^{N} \bar{X}_i}{N}$	Represented by the average of the schooling levels of the owners of agricultural production facilities of sugarcane. It collaborates for the understanding of the sociodemographic profile.
Sex	$\bar{X} = \frac{\sum_{i=1}^{N} \bar{X}_i}{N}$	Represented by the average gender of the owners of agricultural production facilities of sugarcane. It collaborates for the understanding of the sociodemographic profile.
Size of Production Facility	$\bar{X} = \frac{\sum_{i=1}^{N} \bar{X}_i}{N}$	Measured by the average size of rural properties, an important variable for cost analysis and potential remuneration. In this study, production facilities in the smallholding, small, medium and large classes were identified, measured in hectare (ha).
Total Operating Costs by cane	$TOC_{cane} = \left[\frac{\text{Cost}}{\text{Remuneration}}\right]$	It includes operational disbursements, such as: inputs, labor, machinery, administrative expenses, pro labore and depreciation. For the aim of this study, TOCcane was calculated in relation to the 2017/2018 sugarcane harvest in the production facilities.
Type of Contract	$\bar{C} = \frac{TC}{N}$	Represented by the ratio of the incidence of modalities of the types of contracts of agricultural production facilities. It collaborates for the understanding of allocation of costs.
Upgrade	$\bar{X} = \frac{\sum_{i=1}^{N} \bar{X}_i}{N}$	Represented by the average of the groups of the technical update levels of the owners of agricultural production facilities of sugarcane. It collaborates for the understanding of the sociodemographic profile.
Benefit Index: Sugar cane Cost by Profile	$\text{IBCcane}\mathbf{pp} = \text{IBCcane} * \bar{x}$	The IBCcane**pp** (sugar cane) aims to compare the benefit-cost range as a function of the production scale capacity of rural establishments. However, it is noteworthy that, for conclusive purposes of the results, the model needs in other regions validation tests for wide application of the equation (Souza, 2013; Trueb, 2013). **Where it is read**: IBCcane**pp** (sugar cane) = Benefit-Cost Index by Group Profile, relative to the size of the rural establishments; $\bar{x}$ = Average of rural areas by profile (INCAR - National Institute of Colonization and Agrarian Reform, 2017).

Source: Adapted from Lund (2012); Souza (2013); Trueb (2013); CONSECANA (2018) and Treasy (2018).

The model adjustment used the multiple linear regression equation that aims to create a standard model that explains the factors that influence the IBCcane through the advanced Forward Stepwise selection method and aims to select the variables that most impact the response variable with the input method and factor removal by the Akaike information criterion, which includes the effects of the variables to compose the regression equation. The selection of variables was performed dynamically, maintaining only variables with statistically significant coefficients ($P<0.05$), and those with higher significance were removed (Navarro *et al.*, 2010). The adjusted regression model verified that only 7 variables have a causal relationship with the response variable (significance $P<0.05$). Based on this final selection, and in order to obtain more information, we analyzed the segmentation of the socioeconomic rates for the characterization of the model.

The analysis of the adjusted model was deepened with the application of segmented rates according to the profiles of the agricultural production facilities, considering their size. The agricultural production facilities were classified according to their size, adopting the regulations of the National Institute of Colonization and Agrarian Reform (INCRA or *Instituto Nacional de Colonização e Reforma Agrária*) and the applicable Brazilian legislation that establishes as unit of measurement the module (territorial unit), and its value varies according to each city. For Quirinópolis, the agricultural production facilities are considered smallholding, if the area is less than 1 fiscal module (0 to 30 ha), small, if the property of the area comprised is between 1 and 4 fiscal modules (30.01 ha to 120 ha), medium, if the area is greater than 4 and up to 15 modules (120.01 ha to 450 ha), and large, if the rural property of the area is greater than 15 fiscal modules (over 450.01 ha) (INCAR, 2017).

4. RESULTS AND DISCUSSION

The methodology of extraction of the construct's dimensions used the CATPCA with IBCcane as labeling variable for analysis of the Type of Contract, TOCcane, ISC, Size of Production Facility, Sex, Agroindustry Distance, Upgrade, Schooling, Associate, IA, Remuneration, IEcane, Age, IBA, Previous Activity, Microregion and Identification variables.

The CATPCA analysis was accepted as valid by the Cronbach's alpha coefficient, which was based on the auto value of the rotated variables and obtained values above 0.70 and below 0.95 in two dimensions, being dimension 1, 0.760, and dimension 2, 0.738, in Cronbach's alpha. The CATPCA analysis adopted the extraction method via Principal Component Analysis and the Varimax Rotation method with Kaiser Normalization. The variables with negative values were excluded considering the expected values for the model of analysis and dimensioning between "0 and 1". The normality was assessed, with satisfactory results, observing that three variables did not present a normal distribution. The Kolmogorov-Smirnov test applied to the variables tested the significance at $P<0.05$ and, additionally, Friedman's ANOVA was applied for hypothesis testing to verify rejection of the null hypothesis, with performance at 95% reliability.

The CATPCA method can be considered as an exploratory technique to reduce the dimensions of a database incorporating nominal, ordinal and numerical variables. This is appropriate when it is intended to reduce the dimensionality of variables measured at different scales in one or more rates, classified as a multivariate analysis technique, in order to measure the interdependence between the research objects for grouping according to attributes (Navarro *et al.*, 2010). It is important to mention that the objective of the factorial plans is not to relate two factors separately, but to represent the variables in a two-dimensional plan to better analyze their behavior.

Table-2. Model summary rotation: coefficient CATPCA, test for hypothesis and normal testing.

Description	Dimension		Test Kolmogorov-Smirnov
	1	2	P-value
Type of contract	0.939		0.049*
TOCcane	0.918		0.001
ISC	0.442		0.000
Size of production facility	0.392		0.000
Sex	0.280		0.000*
Agroindustry distance	0.053		0.004
Upgrade		0.736	0.000
Schooling		0.611	0.002
Associate		0.560	0.000**
IA		0.463	0.000
Remuneration		0.406	0.200
IEcane		0.385	0.000
Age		0.342	0.200
IBA		0.129	0.200
Previous activity		0.188	0.002
Microregion		-0.163	-
Identification		-0.109	-
Variance accounted (self value)	3.492	3.223	
Cronbach alpha	0.760	0.738	
Analysis of variance of friedman factors by related sample stations	Reject the null hypothesis.	Significance: 0,000	

*Binominal test of a sample ** Chi-square test of a sample. Usual abbreviations of variables: Index Benefit Cost by cane (IBCcane); Index Associative (IA); Index Business Attractiveness (IBA); Index Exodus by cane (IEcane); Index Succession Capacity (ISC) and Total Operating Costs by cane (TOCcane).

The variables with the CATPCA were explored in order to summarize a model with the most interconnected variables and two dimensions were obtained, as shown in Table 2 in which it can be inferred that dimension 1 with its components explains 52% of the variance and obtained the Cronbach's alpha value at 0.76, placing within a reliability range and dimension 2 also showed internal consistency obtaining the Cronbach's alpha index value at

0.74 (Navarro *et al*., 2010). The study, after these statistical tests and the determination of the dimensions by the CATPCA method, rejected the variables Microregion, Identification, Remuneration, Age and IBA Table 2.

4.1. Adjustment of Regression Model and Segmented Exploration of the Equation

In this section, after the selection of the factors by means of statistical techniques, the regression model was developed. The F test of global significance demonstrated that the adjusted multiple linear regression model is useful to predict the response variable (IBCcane) when obtaining the P-value<0.05, that is, there is statistical evidence. Predictors that were tested to compose the model at a significance level of P-value<0.05 for validation: Type of Contract, TOCcane, ISC, Size of Production Facility, Sex, Agroindustry Distance, Upgrade, Schooling, Associate, IA, IEcane, and Previous Activity. Remuneration, Age, Microregion, Identification and IBA predictors were excluded for statistical insignificance (P>0.05).

Table-3. Evaluation of the regression model by the test F, IBCcane (dependent variable).

Model*	Coefficient	Standard error	P-value	df	F test	
					F	Significance
Model adjusted	9.203	1.615	0.000	7	34.046	0.000
Size of production facility	0.004	0.001	0.000	1	22.300	
Type of contract	5.556	1.269	0.000	1	19.186	
TOCcane	-8.266	2.466	0.003	1	11.236	
Schooling	-1.976	0.761	0.018	1	6.739	
IEcane	0.361	0.151	0.027	1	5.738	
ISC	-0.480	0.204	0.020	1	5.559	
Agroindustry distance	-0.111	0.052	0.045	1	4.583	

*Chi Square (R^2) adjusted = *0.899*. Usual abbreviations: Index Benefit Cost by cane (IBCcane); degree of freedom (df); Index Exodus by cane (IEcane); Index Succession Capacity (ISC) and Total Operating Costs by cane (TOCcane).

The global significance F test demonstrated that the adjusted multiple linear regression model is useful for predicting the response variable (IBC sugar cane) when obtaining the P < 0,05, that is, there is statistical evidence. They were tested to compose the model at the significance level at P <0,05 for validation the predictors: Type of Contract,COT_{cane}, ICS, Establishment Size, Gender, Agro-Industry Distance, Update, Schooling, Associate, IA, IE sugar cane, and Previous Activity. For statistical significance (P> 0.05), the predictors Sex, Update, Associated, AI and Previous Activity were excluded.

The individual significance tests demonstrated acceptable reliability for the explanatory variables: Type of Contract (P-value = 0.000), TOCcane (P-value = 0.003), Size of Production Facility (P-value = 0.000), Agroindustry Distance (P-value = 0.045), Schooling (P-value = 0.018), IEcane (P-value = 0.027), ISC (P-value = 0.020) and the (P-value = 0.000) intercepto, in which variability is explained at the level of 89.9% of the response variable. (IBCcane). The F test was also used as a selection criterion, which was adopted in this study with 5% significance (Alves, 2013). The adjustment method adopted was linear models by classification, through IBM® SPSS Statistics 24.0 and Microsoft® Office Excel, which summarized in the model the Type of Contract, TOCcane, Size of Production Facility, Agroindustry Distance, Schooling, IEcane and ISC predictors.

The Size of Production Facility, Type of Contract and TOCcane predictors have an impact of 70% on the equalization of the proposed model found in dimension 1 of the CATPCA and, more specifically, in the first two (55.1%), which demonstrate a positive impact intrinsically linked to the condition of entry into the sugarcane production system, in which the larger the Size of Production Facility and by choosing Type of Contract, the greater the result of IBCcane in function of the proposed model, while TOCcane acts as a deflator. The calculations of the adjusted model showed an adjusted R-squared (0.899) with a strong relation of the explaining variables of the variability of the response variable, at the confidence level of 95%.

In this study, it was found that the coefficients positively impact the equation: Type of Contract, Size of Production Facility and IEcane. These are variables with a negative impact: Agroindustry Distance, TOCcane, Schooling and ISC. The prediction model of the IBCcane value is determined by the equation: IBCcane = 9.203 + 0.004*Size of rural Production Facility+5,556*Type of Contract -8.266*TOC_cane - 1,976*Schooling+0,361*IEcane-0,480*ISC-0,111*Agroindustry Distance+1,615.

Table-4. Socioeconomic indexes segmented according to the size of the agricultural production facility.

Index/Variable	**Profile of the rural establishment by size**				**General Average**
	0 to 30 ha	**30.1 to 120 ha**	**120.1 to 450 ha**	**+ of 450 ha**	
Size of production facility *	17.42	64.69	251.47	1,571.57	756.63
Agroindustry distance**	17.67	12.56	22.84	25.38	22.03
Schooling					
Incomplete medium	1.00	0.33	0.57	0.52	0.53
Medium	0	0.33	0.29	0.12	0.21
Superior	0	0.33	0.14	0.36	0.26
Type of contract					
Production	0	0.67	0.55	0.79	63.79
Lessor	1.00	0.33	0.45	0.21	36.21
IEcane	1.00	0.48	0.05	-0.27	-0.09
ISC	0	3.18	3.26	3.97	3.47
Vocation	0	3.18	3.16	3.80	3.38
Pratical abilit	0	3.39	3.56	4.10	3.68
Technical training	0	2.98	3.07	4.00	3.35
IBCcane	24.39	2.70	3.29	1.76	2.46
Rcane	870.99	1,405.11	978.54	1,558.49	1,203.28
TOCcane	0.04	0.40	0.36	0.80	0.41
IBCcane *by profile*	424,39	174,66	827,34	2.765,96	1.861,31

Note. * The size of the rural establishment is expressed in hectares. ** Distance from agribusiness is expressed in Km. *** Benefit Cost and per profile measured in points. Usual abbreviations: Index Benefit Cost by cane (IBCcane); Remuneration by cane (Rcane); Index Exodus by cane (IEcane); Index Succession Capacity (ISC) and Total Operating Costs by cane (TOCcane).

The characterization of the sample shows a conversion of 100% of the smallholdings to the lease-type contract and a predominance of the production-type contract in the large-sized production facility. The smallholdings and small production facilities are at an average distance of 15.11 km from the agroindustry, and the medium and large ones at about 24.11 km. Regarding the level of schooling, it can be seen that, with the increase in the size of production facilities, the level of schooling also increases. The results related to the rural exodus rate in rural production facilities showed that smallholdings follow the national trend with a high rate of rural exodus (100%) (IBGE, 2018a; Nacife *et al.*, 2019).

It is possible to verify that a downward curve is formed from this trend. As the size of agricultural production facilities increases, the curve slopes downwards, making the rate negative. It can be noticed that the rural exodus rate in this research is directly linked to the type of contract and combination with the profile relative to the size of the agricultural production facility Table 4.

In relation to the training of successors, it was found that there were no successors in the smallholdings sampled. The evaluation of the vocation, practical skill and technical training variables is increasing according to the size of the rural property. This rate obtained a score considered good, qualified with 69.4% (scale 0 to 100%) by the owners, specifically of the agricultural production facilities in this study. The ISC obtained is positive in the sense of family succession of the business, but it presents a result that the smaller the rural property, the lower the training of the successors currently, and the technical training variable is the one that most expresses this condition, also appearing as the one that is more linked to socioeconomic issues (Burton and Fischer, 2015; Morais *et al.*, 2017).

The observation of the profiles of the rural establishments reveals that the best score of the IBCcane was of the smallholdings with 24.39 ha^{-1}, graduating in 100% by lessors. Already the IBCcane by profile that considers the ratio IBCcane X average area of the establishments was: 424.39 (minifundium); 174.66 (small); 827.34 (average); and 2,765.96 (large), allowing us to infer that the medium and large agricultural establishments in the sector have a better benefit-cost ratio due to the predominance of the type of contract, but the large rural establishment will receive greater cost-benefit and consequently profit, as a result of its productive potential, provided by the gain of production scale (Helfand and Levine, 2004; Střeleček *et al*., 2011; Pokharel and Featherstone, 2019). The IBCcane was an indicator proposed in this study, but it is emphasized, however, that for conclusive purposes of the results, the model needs validation in other regions for wide application of the equation (Souza, 2013; Trueb, 2013).

5. CONCLUSIONS

CATPCA Summary Model Rotation combined with multiple linear regression validated the composition of a two-dimensional equation model of the main socioeconomic variables predicting the benefit-cost index for the sugarcane production system. The economic analysis of the rural establishment has shown that the smallholdings have the best benefit-cost per hectare ratio and the larger ones have the highest profit due to the gain in scale promoted by their size which impacts on the total benefit-cost-per-hectare ratio.

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