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Evaluation of the Use of Multivariate Statistical Techniques in Theses and Dissertations of Some Higher Education Institutions

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Abstract

This paper is part of a large study to assess the suitability of the use of multivariate statistical techniques in theses and dissertations of some higher education institutions in the area of marketing in the theme of consumer behavior from 1997 to 2006. Eleven multivariate techniques (regression analysis, discriminant analysis, logistic regression analysis, canonical correlation, multivariate analysis of variance, conjoint analysis, structural equation modeling, factor analysis, cluster analysis, correspondence analysis, multidimensional scaling) are focused on in this paper, which have presented great potential for use in marketing studies. This study aimed at analyzing the suitability of the use of these techniques to the needs of the research problems presented in theses and dissertations as well as measuring the level of success in meeting their assumptions. Overall, the results suggest the need for an increased commitment of researchers to verify all the theoretical precepts of employment of the multivariate techniques.

Keywords:

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1 Introduction

Several works of the 1990s have addressed the issue of quality of scientific production in Administration, highlighting: Finance (LEAL *et al*, 2003); Marketing (POWERS *et al*, 1998; VIEIRA, 1998; BOTELHO e MACERA, 2001); Quantitative Methods (BREI e LIBERALI, 2004); Operations (ARKADER, 2003), Organizations (BERTERO e KEINERT, 1994; VERGARA e CARVALHO, 1995; BERTERO *et al*, 1999; RODRIGUES FILHO, 2002), Research in Business Administration (MARTINS, 1994; TORRES, 2000; PERIN, 2002); Human Resources (ROESCH *et al*, 1997; CALDAS *el al* 2002; TONELLI *et al*, 2003), Information Systems (HOPPEN, *et al*, 1998).

The concern of the authors of these works has been directed towards the discussion both on epistemological factors and on methodological factors, in which for this second branch, the number of studies found in the literature is considerably reduced.

Quantitative methods were widely used in dissertations and theses presented at Faculdade de Economia, Administração e Contabilidade da Universidade de São Paulo, Faculdade de Economia e Administração da Pontifícia Universidade Católica and Escola de Administração da Fundação Getúlio Vargas, between the years 1980 and 1993, according to Martins (1994, p.65-66), who highlighted the superficial use of the techniques in the evaluation of these works, regardless of their level of complexity and sophistication. Such superficiality is also highlighted by the author, in the apparent unconcern with the theoretical assumptions for the implementation of most of the methods presented in these works.

For Gamboa (1987, p.17), the importance of analysis of scientific production, supported in methodological competencies, is justified, since it is of fundamental and decisive importance for the development and results of academic research.

In the quantitative treatment of the data for scientific production the use of multivariate analysis has been increasing, due to the fact that, in recent decades, several statistical computer packages have improved greatly in making their content away from mathematical complexities inherent to them.

Technological developments in statistical software has provided greater ease of operation in multivariate analysis tools, contributing to the reduction of barriers for users and meeting adequately the demands of scientists of applied social sciences, including Business studies. However, errors of employment have been detected, either in the inadequacy of the goals in using tools with the proposed research objectives, or in the violation of the assumptions in techniques implementation.

The multivariate analysis tools have been widely applied in marketing, especially on the topic of Consumer Behavior. For Milagre (2001, p.74), the use of multivariate technique became more common from the time that academics and marketers began to apply it in studies on consumer preference and satisfaction, as well as consumer profile and shopping behavior.

In this context, the objectives to be achieved in this study are:

1. Identify the intensity of use of multivariate techniques in the area of Marketing, on the theme of Consumer Behavior, having as the unit of analysis dissertations and theses in the period 1997-2006, in two public Brazilian universities: Faculdade de Economia, Administração e Contabilidade da Universidade de São Paulo and Escola de Administração da Universidade Federal do Rio Grande do Sul.
2. Identify the level of appropriateness of the use of multivariate techniques to research problems presented in these selected theses and dissertations.
3. Identify sources of errors of the employment of multivariate techniques, from not meeting their basic assumptions, throughout the examined scientific production.

The selection of these Graduate Programs as target audience of this study was due to the need for delimitation, given the operational difficulty of a representative sample survey of domestic production, mainly given the unavailability of material in *online* database of a significant portion of institutions in the country. A second criterion was due to the need to ensure the greatest possible homogeneity of the target population, since no specific objective of this study is the comparison between institutions.

2 Theoretical Foundation

In this section there will be an introduction to multivariate analysis, followed by an overview of multivariate techniques and their assumptions.

2.1 Multivariate Analysis
According to Steiner (1995), the need to understand the relationship between several random variables turns multivariate analysis a methodology with great potential use.
For Lourenço and Matias (2001), on the one hand, the multivariate statistical techniques are more complex than those of univariate statistical context.

2.2 Statistical techniques of multivariate analysis
The choice of methods and types of analysis employed in scientific papers should be determined by the research problem.
The next step for choosing the technique of multivariate analysis is to check the type of relationship, the number of dependent variables and the type of scale used.
Regarding the type of relationship, the techniques are classified as dependence or interdependence. In the first situation one or more variables can be

explained or predicted by other. In the second, all variables are analyzed simultaneously, without the orientation of dependence.

Concerning the type of scale, there is two main groups: non-metric variables and metric variables.

2.3 Assumptions of multivariate techniques

Table 1 shows the relationship of theoretical assumptions in the employment of multivariate techniques and indication, using X in each technique that has association with certain condition. Conjoint analysis is not included within this framework because no theoretical assumptions apply to this technique.

Table 1. *Assumptions underlying the use of multivariate techniques*

Techniques[*] Assumptions	1	2	3	4	5	6	7	8	9	10
Low multicollinearity	X	X	X	X	X	X	X	X		
Absence of correlated errors	X			X						
Absence of atypical observations	X	X	X	X	X	X		X		
Correlation between variables predicted					X					
Homoscedasticity	X	X		X	X					
Linearity	X	X		X	X	X	X			
Multivariate normality		X		X	X	X	X			
Univariate normality	X									
Number of variables										X
Number of categories for variable									X	
Number of dimensions										X
Standardization of variables							X	X		X
Sample Size	X	X	X	X	X	X	X	X	X	X
Group size		X								

[*] 1 - regression analysis, 2 - discriminant analysis, 3 - logistic regression analysis, 4 - canonical correlation, 5 - multivariate analysis of variance, 6 - structural equation modeling, 7 - factor analysis, 8 - cluster analysis, 9 - correspondence analysis and 10 - multidimensional scaling

2.3.1 Multicollinearity
Multicollinearity is the extent to which a variable can be explained by the other variables in the analysis. As multicollinearity increases, it is more difficult to ascertain the effect of any single variable, owing to their interrelationships (HAIR *et al*, 2005, p. 2).

2.3.2 Lack of correlated errors (residuals autocorrelation)
According to Kendall and Buckland (1971, p.8), the meaning of autocorrelation can be understood as the 'correlation between members of series of observations ordered in time (time series) or in space (cross-section)'.
In the scope of the techniques regression analysis and canonical correlation, it is assumed that the error referred to a prediction is not influenced by any mistake of any other prediction.

2.3.3 Outliers
The atypical or extreme observations (outliers) are substantially different from those of others.
Regarding the multivariate outliers, these are cases with extreme values on the set of multiple variables and are operationally defined by three measures most commonly used in most commercial statistical packages: Cook's Distance, Mahalanobis Distance and Leverage Distance (HAIR *et al,* 2005).

2.3.4 Correlation between variables predicted
The dependent variables in MANOVA must have a certain degree of correlation; otherwise it would be advisable to employ the univariate analysis of variance for each of the dependent variables.
Individual tests performed for the dependent variable in univariate analysis of variance (ANOVA) ignore the correlations between the dependent variables and use less than the total information available to assess the overall differences between the groups. When the dependent variables have correlation between them, the MANOVA has greater power to detect significant differences in the groups than the ANOVA.

2.3.5 Homoscedasticity
When the variance of the error terms seems constant over the area of the predictor variable, there is homoscedasticity (HAIR *et al,* 2005).
Homoscedasticity may initially be verified by residual plots (errors). The graphs of the errors against the actual values and the values predicted are important. If the points are randomly distributed without showing a defined behavior, there is homoscedasticity.

2.3.6 Linearity
According to Hair *et al* (2005), in general, linear models predict values that fit to a straight line, which has a unit constant with change in the dependent variable with respect to a constant change in the independent variable.

A simple inspection of the graphs as scatterplot is a common and simple method to check the linearity. In addition, correlation analysis and other more complex tests are available for detecting this premise.

2.3.7 Normality
In multivariate statistical techniques that use metric variables and statistical tests for the analysis of the results, the multivariate normality is the most fundamental condition of employment. However, in the case of the regression analysis, there is the assumption of univariate normality, considering only the variable referring to residuals.

2.3.8 Number of Variables
For the proper implementation of multidimensional scaling technique, the number of variables must be greater than or equal to 3, according to Hair *et al* (2005).

2.3.9 Number of categories by variable
One requirement of correspondence analysis technique is that the minimum number of categories per variable should be 3, but without being too high, according to Hair *et al* (2005).

2.3.10 Number of dimensions
For the use of multidimensional scaling, the number of dimensions cannot exceed the number of cases. If there are more dimensions to objects, the technical solution will be unstable. If there are very few objects in relation to dimensions, the adjustment measures are falsely good (LOURENÇO and MATIAS, 2001).

2.3.11 Standardization of variables
The techniques cluster analysis and multidimensional scaling require standardization of metric variables that have different magnitudes. In the case of factor analysis, standardization is not a premise, however, can be applied to the data before processing this technique (HAIR *et al,* 2005).

2.3.12 Sample Size
Combined with a correct sampling procedure, the sample size (number of cases, individuals, observations, interviews) should be adequate to allow generalization of the results, which can be checked for statistical significance testing.
The facilities offered by most computer packages for statistical employment may compromise compliance with the minimum sample size by the researcher, a fact that can cause a number of important problems. For Hair *et al* (2005), this omission may result in:

- Very low statistical power of significance tests;

- A very suitable adjustment of the data, making the results artificially good.

2.3.13 Group size

One of the requirements for the appropriate use of discriminant analysis technique is the design of each group established by the dependent variable. According to Hair *et al* (2005), each group must have at least 20 observations to establish the discriminant function.

3 Research Methodology

In this section we will present the topics related to: population characterization, design methodology of empirical research, the construction of the criterion of suitability of the employment of multivariate techniques, instrument data collection and outcome variables.

3.1 Characterization of the target population

The population under study includes the dissertations and theses in Business Administration, Marketing area, subject of Consumer Behavior, presented at the Post-Graduate Faculdade de Economia, Administração e Contabilidade da Universidade de São Paulo and Escola de Administração da Universidade Federal do Rio Grande do Sul, in the period between 1997 and 2006.

The universe of interest was defined as a dissertation or thesis, focusing on marketing, specifically consumer behavior, and use of multivariate statistical technique as a tool for problem solving research, presented to PPGA's public institutions with higher CAPES evaluation in the area of Administration.

The population unit, however, refers to the employment of multivariate statistical technique in that universe of interest, and may be more than one employment on each study of the universe of interest.

In the environment identification of the target population of this study, it was registered 196 dissertations and theses on Consumer Behavior (universe - U), 56 dissertations and theses with employment of multivariate statistical techniques (universe of interest - UI) and 99 employments statistical techniques of multivariate analysis (target population - TP).

3.2 Methodological design of the research

This study is consistent with the quantitative approach, using content analysis.

The option to use the technique of content analysis was driven especially by the primary need of this study to interpret the problem situation of selected theses and dissertations in order to identify the process of its solution by selecting a multivariate statistical technique appropriate.

On the one hand objectivity is sought quite intensely (RICHARDSON, 1999, p.221) to categorize the problems of dissertations and theses, by defining strict criteria for judging the solution of these problems. On the other, the general process of evaluations to be implemented to units of analysis (theses and

dissertations) is contaminated by judgments, insofar as content analysis also assumes the examination of characteristics absent or partial records of meeting the assumptions of the statistical technique used.

3.3. The construction of criteria for evaluating the employment of multivariate techniques

Two criteria are presented below in order to assess the degree of success in the employment of multivariate techniques.

3.3.1 Procedure of categorization of the research problem of the unit of analysis: Criterion 1

The orientation to categorize the research problem of each analysis unit was given by the purpose of employment of different statistical techniques of multivariate analysis. According to Johnson and Wichern (1998, p.2), the categories are summarized in five ways:

- Data reduction or structural simplification;
- Grouping;
- Dependence between variables;
- Prediction;
- Hypothesis formulation and testing.

The category identified in the unit i of analysis was confronted with the category-objective of multivariate techniques. The assessment made by this confrontation has a dichotomous character. It was considered a proper employment of multivariate technique when category-objective of employment of the technique met the category of the research problem of unit i of analysis.

3.3.2 Procedure for assessment of compliance with the assumptions of multivariate techniques: Criterion 2

Meeting the assumptions of multivariate techniques was due to confirmation that all assumptions postulated by theory were met. A violation of at least one of the assumptions outlined in the content featured in the unit i of analysis, as well as no explanation of the situation of each premise (care or not care) resulted in category: not meeting the assumptions.

3.3.3 Final evaluation of the suitability of the use of multivariate techniques

The record level of appropriateness of the use of multivariate techniques was done in three levels:

- Level 1 (No suitability of use of the technique): no adjustment of the category-objective of techniques applied to the category of the research problem of unit i of analysis, regardless of the compliance or noncompliance to the assumptions of this technique.
- Level 2: adjustment of the category-objective of techniques applied to the category of the research problem of unit i of

analysis and not meeting to at least one of the assumptions of the technique in the document unit i.

- ▪ Level 3: adjustment of the category-objective of techniques applied to the category of the research problem of unit i of analysis and meeting to all the assumptions of the technique in the document unit i.

4 Analysis of results

The first step in analyzing the results sought to present evidence as to the intensity of use of multivariate techniques in general, as the goal a.

The second part, as the goal b, dealt with the suitability of the use of multivariate techniques to research problems of dissertations and theses under review.

The third part identified from not meeting the basic assumptions of these techniques, potential sources of error.

4.1 Results for the goal a

The theses and dissertations under study showed more intensive use of multivariate statistical techniques to meet the goal of reducing or simplifying the structure of data collected (62.5%), with the employment of the Exploratory Factor Analysis technique (35 cases).

The research category of dependence between variables was the second most used (46.4%). In this context, six multivariate analyses show that category as one of the goals of employment: Regression Analysis (15 cases), Discriminant Analysis (3 cases), Multivariate Analysis of Variance (3 cases), Conjoint Analysis (3 cases), Logistic Regression (1 case) and Canonical Correlation (1 case).

The category of construction and testing hypotheses was represented in this study by the Structural Equation Modeling technique with 19 cases (33.9%).

The grouping of objects or variables category was used in 18 studies (33.9%), with the highest number of cases with the use of Cluster Analysis (12 cases), followed by Correspondence Analysis (5 cases) and Multidimensional Scaling (1 case).

Only one of the selected studies was used to the prediction of some phenomenon or fact (logistic regression).

In 64.3% of the selected studies, at least two techniques are used to care for problem solving research. The most intensive use of the techniques is, in relative terms, in theses (81.2% of cases) against 57.5% in the dissertations, suggesting greater sophistication of studies in the first group.

4.2 Results for the goal b

A positive outcome of this study is the consistency in selected theses and dissertations regarding the suitability of multivariate techniques to the research problem.

Thus, regarding the criterion 1, all employments of multivariate techniques are appropriate.

4.3 Results for the goal c
Table 2 shows the rates of compliance with the assumptions of multivariate techniques that were recorded in the analysis of dissertations and theses studied in this work.

Table 2. *Meeting the assumptions - % of total cases in each technique*

Techniques [*] / Assumptions	1	2	3	4	5	6	7	8	9	10
Low multicollinearity	21.1	66.7	100	100	33.3	42.1	65.7	25.0		
Absence of correlated errors	15.8			0						
Absence of outliers	0.0	0.0	50	0	66.7	68.4		25.0		
Correlation between variables predicted					100					
Homoscedasticity	10.5	33.3		0	100					
Linearity	10.5	0.0		0	0.0	42.1	17.1			
Multivariate normality		0.0		0	0.0	25.0	2.9			
Univariate normality	15.8									
Number of variables										100.0
Number of categories for variable									100.0	
Number of dimensions										100.0
Standardization of variables							88.6	91.7		0.0
Sample Size	78.9	33.3	100	100	100	84.2	94.1	66.7	60.0	100.0
Group size		100								
Total cases	15	3	2	1	3	19	35	12	5	1
Attend **any** premise	52.6	0.0	0.0	0	0.0	5.3	8.6	0.0	0.0	0.0
Up to **50%** of assumptions met	68.4	100	0.0	100	0.0	21.1	74.4	25.0	0.0	0.0
More than 50% of assumptions met	10.5	0.0	50	0	100	78.9	25.7	75.0	100.0	100.0
All assumptions met	6.7	0.0	50	0	0.0	15.8	11.4	8.3	0.0	0.0

[*] 1 - regression analysis, 2 - discriminant analysis, 3 - logistic regression analysis, 4 - canonical correlation, 5 - multivariate analysis of variance, 6 - structural equation modeling, 7 - factor analysis, 8 - cluster analysis, 9 - correspondence analysis and 10 - multidimensional scaling

The techniques of regression analysis, discriminant analysis and canonical correlation showed low levels of compliance with the assumptions underlying its use. Only 10.5% of the studies met more than half of the assumptions of regression analysis and none of the few cases of employment of discriminant analysis and canonical correlation served more than half of the assumptions. Regarding the logistic regression, MANOVA and structural equation modeling, high rates of meeting of more than half of their conditions (50%, 100% and 78.9%, respectively) were found.

The technique of regression analysis was the one with the fewest assumptions met. More than half of dissertations and theses (52.6%) did not respond to any of the assumptions required. With the exception of the sample size, none of the assumptions presented more than 25% of meeting, with negative highlight for homoscedasticity and linearity, with meeting by 10.5% of the studies each one.

Regarding the logistic regression analysis, the employment was less impaired due to the small number of assumptions that need to be met.

As for the canonical correlation on multicollinearity, its verification occurred through a process of inertia, since factor scores were the input variables of this technique that were already built with low correlations by factor analysis.

Regarding multivariate analysis of variance, in neither case the assumption of linearity was verified and in only one, the premise of multicollinearity was observed.

The structural equation modeling showed the highest number of assumptions met: 78.9% of works met more than 50% of the required assumptions.

The factor analysis showed low levels of compliance with the assumptions underlying its use. Only 25.7% of the studies met more than half of the assumptions and only 11.4% met all the assumptions of this technique.

The cluster analysis showed a significant number of assumptions met (75% meeting more than 50% of the assumptions). Let it be noted that the two assumptions that demanded greater participation of the researcher (multicollinearity and treatment of atypical observations - outliers) are those with a lower rate of use (25% each).

In the five cases with the employment of correspondence analysis two of the three assumptions found in the literature were met. The condition not met in some studies was the assumption for the sample size sufficient to guarantee the expected frequencies greater than or equal to 5.

In the only work with the employment of multidimensional scaling, three of the four assumptions were met. The exception occurred for the premise of standardization of variables.

4.4 Criterion 2 of assessment of levels of suitability in the use of multivariate techniques

The final result of the evaluation of employments found in the target population suggests a fragile operating environment of employment of multivariate techniques in relation to their use and specifically to the meeting of the respective assumptions.

The use of the criterion 2 in the evaluation process reveals that, respectively, 6.7%, 0.0%, 50%, 0%, 0%, 15.8%, 11.4%, 8.3%, 0% and 0% of the employments of regression analysis, discriminant analysis, logistic regression analysis, canonical correlation, multivariate analysis of variance, structural equation modeling, factor analysis, cluster analysis, correspondence analysis and multidimensional scaling fully met their assumptions.

4.5 Final evaluation of the suitability of the use of multivariate techniques
The final assessment of the suitability of the use of multivariate techniques can be synthesized by percentage rates from three levels:
- Level 1: 100% of employments from eleven multivariate techniques (including conjoint analysis) showed convergence between category-objective employment of each technique to the category of the research problem;
- Level 2: 93.3% (linear regression), 100.0% (discriminant), 50% (logistics), 100% (canonical correlation), 100% (MANOVA), 84.2% (structural equation modeling), 88.6 % (factorial), 91.7% (clusters), 100% (correspondence) and 100% (scaling) of the employments of the techniques partially met its assumptions;
- Level 3: 6.7% (linear regression), 0.0% (discriminant), 50% (logistics), 0% (canonical correlation), 0% (MANOVA), 15.8% (structural equation modeling), 11.4 % (factor analysis), 8.3% (cluster analysis), 0% (correspondence analysis) and 0% (multidimensional scaling) of the employments of the techniques presented adequate use regarding the meeting of their assumptions.

5 Conclusions

In the studies evaluated, the solutions to the problems of research focused on the use of techniques of structural simplification or reduction of the data (62.5% of studies), followed by investigation dependence techniques between variables (46.4% of studies).
It is worth noting the success of the analysts in the identification of favorable situations for the use of multivariate techniques in solving research problems of dissertations and theses focused in this study.
As for the quality of employment of these techniques, we wish to highlight that the verification of all its assumptions was found in only 6.7% (linear regression), 0.0% (discriminant), 50% (logistics), 0% (canonical correlation), 0% (MANOVA), 15.8% (structural equation modeling), 11.4% (factor analysis), 8.3% (cluster analysis), 0% (correspondence analysis) and 0% (multidimensional scaling).
Thus, although the findings of this study cannot be extrapolated to the production of other academic institutions or other periods of time, they suggest the need for greater care in employments of multivariate techniques.
It is hoped that the result obtained in this study on the high level of no suitability of the use of multivariate techniques in the target population, due to

not checking all assumptions, be an encouragement for researchers to search for a deeper understanding thorough techniques to be employed as part of the process of solving the research problem, in order to minimize errors arising from inadequate employment.

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