Mundo Fesc E-ISSN: 2216-0388 P- ISSN: 2216-0353 Artículo Original

Discriminant and multivariate analysis of the financial management of banking establishments according to the Financial Superintendence of Colombia

Análisis discriminante y multivariado de la gestión financiera de los establecimientos bancarios según la Superintendencia Financiera de Colombia

Recibido: 24 de junio de 2022
Aprobado: 25 de noviembre de 2022

Forma de citar: J.B. Bayona-Soto, G.T. Navarro-Claro, C.A. Pacheco-Sánchez, "Discriminant and multivariate analysis of the financial management of banking establishments according to the Financial Superintendence of Colombia", *Mundo Fesc,* vol. 12, no. S3, pp. 25-41, 2022

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Discriminant and multivariate analysis of the financial management of banking establishments according to the Financial Superintendence of Colombia

Keywords: multivariate discriminant analysis, cluster analysis, banking establishments, financial information, Pearson's distance.

Abstract

The article presents an analysis of the management profiles of banking institutions that report to the Bank Superintendency, specifically to the Financial Superintendency of Colombia, through a cluster analysis using Minitab software and Multivariate Discriminant Analysis (MDA) with SPSS software. A review of the literature related to the study topic was conducted using SPSS software. The literature related to the object of study was initially reviewed through articles published in databases such as Scopus, Wos, Redalyc, and Google Scholar. The type of quantitative research was established through the statistical analysis of information, conducting a statistical analysis of panel data for the period from 2016 to 2021, resulting in 4 clusters, which ratifies the validation of the discriminant function, meaning that the groups have different variance-covariance matrices. It is also concluded that, despite the economic recession in 2020, the relative levels of the financial position indicators of the analyzed banks remained stable.

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Resumen

El artículo presenta un análisis de los perfiles de gestión de las instituciones bancarias que reportan a la Superintendencia de Bancos, específicamente a la Superintendencia Financiera de Colombia, mediante un análisis de clúster utilizando el software Minitab y un Análisis Discriminante Multivariante (MDA) con el software SPSS. Se realizó una revisión de la literatura relacionada con el tema de estudio utilizando el software SPSS. La literatura relacionada con el objeto de estudio se revisó inicialmente a través de artículos publicados en bases de datos como Scopus, Wos, Redalyc y Google Scholar. El tipo de investigación cuantitativa se estableció mediante el análisis estadístico de la información, llevando a cabo un análisis estadístico de datos en panel para el periodo de 2016 a 2021, obteniendo como resultado 4 clústeres, lo que ratifica la validación de la función discriminante, es decir, que los grupos tienen diferentes matrices de varianza-covarianza. También se concluye que, a pesar de la recesión económica en 2020, los niveles relativos de los indicadores de posición financiera de los bancos analizados permanecieron estables.

Palabras clave: análisis discriminante multivariante, análisis de clúster, establecimientos bancarios, información financiera, distancia de Pearson

Introduction

In today's interconnected and rapidly evolving landscape, financial management has ascended to a pivotal role as a fundamental cornerstone for comprehending the myriad economic events that shape our highly globalized world. Scholars such as [1] emphasize the instrumental role of financial information as the primary catalyst that influences decision-making processes, whether it be at the macro-level of countries and regions, or the micro-level of individual sectors and organizations. These academics argue that effective financial management is not merely a function of accounting, but serves as a crucial driver for academic research and pragmatic studies. These studies aim to unearth insights on creating reasonable value and developing a nuanced understanding of the various multifaceted and intricate scenarios that one might encounter during the managerial process. The significance of mastering accounting structures, according to these researchers, extends far beyond mere number-crunching. Instead, it paves the way for a comprehensive, analytical framework that can be applied to identify opportunities and navigate challenges. In this vein, proper financial management becomes an indispensable tool for executives, policymakers, and scholars alike, aiding them in making informed choices and thereby shaping more prosperous and sustainable futures.

The core premise here is that the realm of financial management has evolved to be a fertile ground for advancing our collective understanding of complex economic phenomena, thereby wielding enormous influence over decisions that can have widespread implications on both local and global scales.

In this sense, with the emergence of international financial reporting standards, the need for information assurance and globalization processes, the need to recognize, measure, present and disclose accounting information arises, complying with the requirements of the environment and implementing best practices in financial management and, consequently, in its analysis. However, [2] [3] [4] [5] [6] consider that the analysis of financial information not only responds to the needs imposed by the environment, and add that it responds to internal strengthening needs of the organization, in other words, it is a systematic process that guides decision-making based on the identification of strengths, weaknesses, opportunities and threats, at an economic and financial level.

It is evident that the incorporation of measures and procedures to ensure the rationality of information requires a specific structure that meets the criteria of timeliness, relevance, and reliability to guide the decisioned approach, without neglecting the limitations that may arise in accounting information. Thus, en [7] [8] state that decisions in financial matters are conditioned by the context, the needs of stakeholders and the users of the information, which directly influence the financial analysis process.

According to [9], financial analysis is a management process through which the productivity and competitiveness of a country, economic sector or organization is measured, and, in this

sense, its application allows identifying the state of financial health, the risks associated with liquidity, indebtedness and profitability indicators, as well as patterns related to the different situations and phenomena that interrelate finances. For this reason, it is essential to identify the trends and needs of information users and society in general, in relation to the most influential sectors of the economy in the development of a country. In Colombia, the banking sector is made up of the designated banking establishments, as established by the Financial Superintendency, this sector has a significant impact on the gross domestic product, and the identification of financial behavior in this sector is still incipient.

In relation to the above, the present study was based on the analysis of the financial information corresponding to the period 2016 to 2021 of 25 banking establishments that report to the Financial Superintendence of Colombia, by means of a cluster analysis and a multivariate discriminant analysis (ADM). As results, 4 groups were identified with the first with 7 observations, the second with 15 observations, the third with one (1) observation and the fourth with two (2) observations, presenting an average distance from the centroid of 34,616,644, representative of the level of intra-group homogeneity in the banking establishments analyzed. The multivariate discriminant analysis (MDA) allowed us to accept the null hypothesis that the groups are equal.

Literature Review

To support the research, a bibliographic review was conducted as of November 30, 2022, through a historical documentary approach, by means of a search of specialized databases such as Scopus, Redalyc and Google Scholar. Thus, through the application of the search equation "financial analysis" and "financial management" within an observation window between the years 2000 and 2022, 252 documents were obtained as results. Of these publications, 30 were identified as being directly related to the study of financial management in different areas such as business, management, accounting and social sciences.

One of the striking observations gleaned from the literature review is the conspicuous scarcity of scientific articles that specifically address the subject of financial management within the Colombian banking sector. This gap in existing research serves as a clarion call for academics and professionals alike to delve deeper into lines of inquiry that encompass both financial analysis and management. The end goal of such research endeavors should not only be to enrich the field but also to contribute multifaceted perspectives to the broader discourse surrounding financial and accounting theories. Among the sparse but noteworthy contributions to this area of study is the work [10]. He observes that Colombia's banking sector has undergone a series of significant transformations, particularly in its organizational and operational frameworks, as well as the regulatory landscape that governs it. Castro attributes these alterations largely to the easing of policies during the tumultuous phases of Colombia's economic history. Yet, he also stresses the undeniably crucial role that the banking sector plays in the country's macroeconomic development.

Consequently, Castro argues for the indispensable need for an efficient financial system—one that not only complies with existing regulations but also ensures the most effective use of resources. As the banking sector is often considered the lifeblood of an economy, facilitating the flow of capital and enabling economic activities, its management becomes paramount. Thus, the proper governance of financial and accounting structures within this sector is not merely a legal requirement but a socio-economic imperative that has far-reaching implications for national development. Regarding the evaluation of the results of the financial analysis of companies and economic sectors, [11] consider that it is possible to establish a comparative, under the description of the behavior of indicators such as liquidity, indebtedness, among others, which allow measuring competitiveness. From another perspective, highlight the study of financial management through sectoral dynamics and conclude on the importance of considering official sources to consult accounting information and generate confidence in the data related to economic evolution and performance [12] [13].

For his part, [14] [15] [16] refer to the purpose of competitiveness through the recognition offered by the characteristics of financial management from the processes of comparability, decision-making, and transversality. Additionally, according to [17], indicators such as profitability, liquidity, turnover, and capital structures should be considered, which allow describing in a period of time, the economic and financial context of the companies under study.

About financial analysis in different contexts, [18] proposed a strategic and financial model that promotes comprehensive diagnosis and evaluation, through a review of the behavior of the different factors internal and external to the organization.

Similarly, [19] focused his research on the analysis of performance, and financial management in companies led by men and women, establishing comparatives in their efficiency, structure, profitability, and forms of administration considering environmental factors. In another sense, [20], adds to the financial evaluation and economic acceptance of organizations factors such as environmental impact, moral and the necessary levels of financing for socially responsible productive factors.

On the other hand, authors such have focused their research on the analysis of financial management and its effects on the value chain, integrating comparisons through performance indicators, and making comparisons against an entire economic sector, taking into account the dynamics of the environment; on the other hand they highlight the importance of the quality of financial information for the implementation of improvements in the management systems of organizations independent of their economic activity [21] [22] [23] [24] [25] [26] [27].

Similarly, [19] focused his research on the analysis of performance, and financial management in companies led by men and women, establishing comparatives in their efficiency, structure, profitability and forms of administration taking into account environmental factors. In another sense, [20] adds to.

Finally, it is important to highlight, according in [28] [29] [30] [31] [32] [33] [34] the progress that in recent years, financial analysis and financial management has had, through the work of various investigations, which recognize its interdisciplinarity, and directing knowledge in public dynamics, private, territorial views with business influence; performances in management, strategy, decision-making and evaluation; competitiveness perspectives with transversal and comparative analysis with different space and time delimitations; as well as specific conditions and circumstances of environment and context where it intervenes through the disciplines of financial analysis and financial management, grouping observations and valuation practices as a consequence of the process.

Materials and Methods

In the preparation of this article, an exhaustive evaluation was carried out on the financial data pertaining to the Colombian banking sector, which were reported to the Financial Superintendence over a span of six years, from 2016 to 2021. The data were meticulously arranged in a panel format, a technique aimed at facilitating longitudinal analysis, enabling researchers to track and understand trends and shifts over the specified period.

Following the data arrangement, a more nuanced statistical approach was implemented. Multivariate Discriminant Analysis (MDA) was employed alongside cluster analysis techniques. The primary objective of utilizing these sophisticated methodologies was to gain deeper insights into the sector's financial standing as well as its economic performance. Specifically, these analyses focused on a range of financial variables that include, but are not limited to, assets, liabilities, equity, and internally generated income.

The combined use of MDA and cluster analysis serves a twofold purpose: first, to discriminate between banks based on predefined financial indicators, thereby identifying underlying patterns or trends that might otherwise remain obscured; and second, to classify these financial institutions into clusters sharing similar financial characteristics or performance metrics. This multifaceted approach provides a robust framework for interpreting the dynamic financial landscape of the Colombian banking sector, thereby contributing to both academic discourse and practical applications in financial management and regulatory oversight.

According to [35] Cluster Analysis corresponds to a technique used with the purpose of identifying "hierarchical structures in the partition of the group of observations and the reduction of variables in the dimension of a problem under study". On the other hand, [36] state that this type of analysis provides classifications that can be used to find a set of data similar to each other.

Regarding the data, the financial information of the 25 Banks that reported to the financial superintendence in the period 2016-2021 was used, and the study variables were: Assets (ACT), Liabilities (PAS), Equity (PATRI), income (ING) and result of the exercise (RESUL), the respective analysis was performed in the Minitab software, based on similarity or

distance measurement criteria (Pearson, Complete Link) and grouping (Complete, Ward Centroid) contained in said software. The discriminant analysis was performed using SPSS software to establish the discriminant functions of the study variables, the analysis of the reliability statistics yielded Cronbach's Alpha of 0.963, which indicates that the internal consistency of the items is high. The figure 1 shows the methodological process:

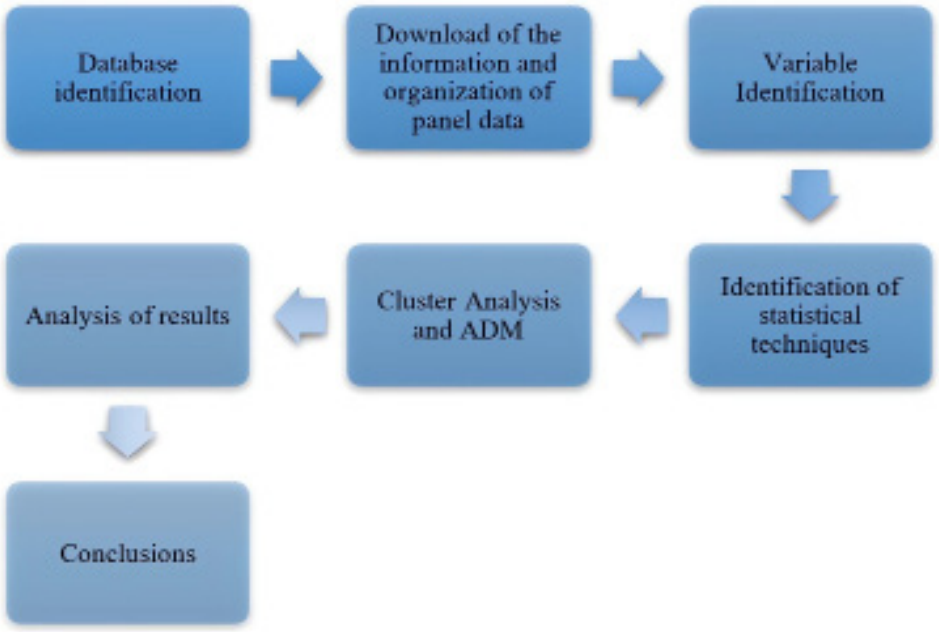

Figure 1. Methodological Process

Results

Cluster analysis

To gain a comprehensive understanding of the various banking establishments reporting to the Financial Superintendence of Colombia within the time frame of 2016 to 2021, a methodical study was undertaken. The research process commenced with an initial analysis focused on "distance levels" between different establishments. This aspect of the study involved using quantitative metrics to categorize and evaluate the banks in question, with the aim of identifying key patterns or commonalities that might exist among them. The analytical techniques utilized in the study were embedded within the Minitab software, which is renowned for its capability to perform intricate statistical analyses.

The software offers a variety of grouping criteria and similarity measures, allowing for a

nuanced evaluation of the data gathered. After exhaustive analysis, the research culminated in the identification of four distinct groups or clusters. These were characterized as intra-group homogeneous profiles, meaning that establishments within each group shared a certain degree of similarities, be it in terms of financial performance, compliance with regulations, or other pertinent factors.

What makes this study particularly noteworthy is its contribution to the broader understanding of the Colombian banking sector's landscape. By leveraging advanced statistical techniques available in Minitab, the research not only identified these clusters but also offered a basis for further research and discussion. Whether for regulatory oversight or strategic business planning, these findings equip stakeholders with valuable insights into the dynamics and intricacies of banking establishments operating within Colombia during the specified period. Through this multi-faceted approach, the study serves as a foundational piece of research that can be used to further explore the complexities and unique characteristics of individual banking establishments, thereby aiding the Financial Superintendence of Colombia and other interested parties in making informed decisions. In essence, the research provides a structured, data-driven lens through which the heterogeneity of Colombia's banking sector can be better understood and managed, as can be seen in the scatter plot figure 2:

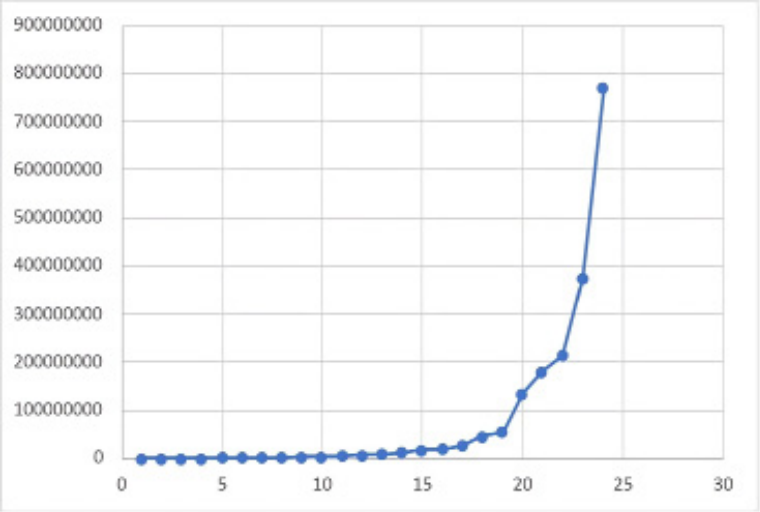

Figure 2. Scatter diagram

Based on the data analyzed through specialized software and corroborated by prior graphical representations, the findings reveal interesting dynamics within the Colombian banking sector. Specifically, the study demonstrates that there exists a substantial degree of intra-group homogeneity, alongside noticeable extra-group heterogeneity, within the banking establishments examined. These observations were based on rigorous analytical processes that employed Pearson distance as a key criterion for what is known as "Complete Link" clustering.

Additionally, similarity measures were incorporated to validate these groupings. In simpler terms, the banks within each identified group or cluster share a high level of similarity with one another, whether it be in terms of financial performance, compliance, or other relevant metrics. Conversely, when comparing banks between different groups, a considerable level of dissimilarity or heterogeneity is observed. Such a pattern is indicative of unique operational or financial characteristics that set each group apart from the others. This adds an extra layer of complexity to the landscape of the Colombian banking sector, suggesting that a one-size-fits-all approach to regulation or management would be inappropriate.

Given these findings, the study makes the compelling argument that it is pertinent to recognize and categorize these banking establishments into four distinct groups or conglomerates based on their financial information. This categorization not only enriches our understanding of the nuances within the sector but also provides regulatory bodies, policy-makers, and industry stakeholders with actionable insights. Knowing the characteristics that make each group homogeneous internally and heterogeneous externally allows for the creation of targeted strategies and regulations that can better address the unique challenges and opportunities each group presents, as shown in the dendogram in figure 3.

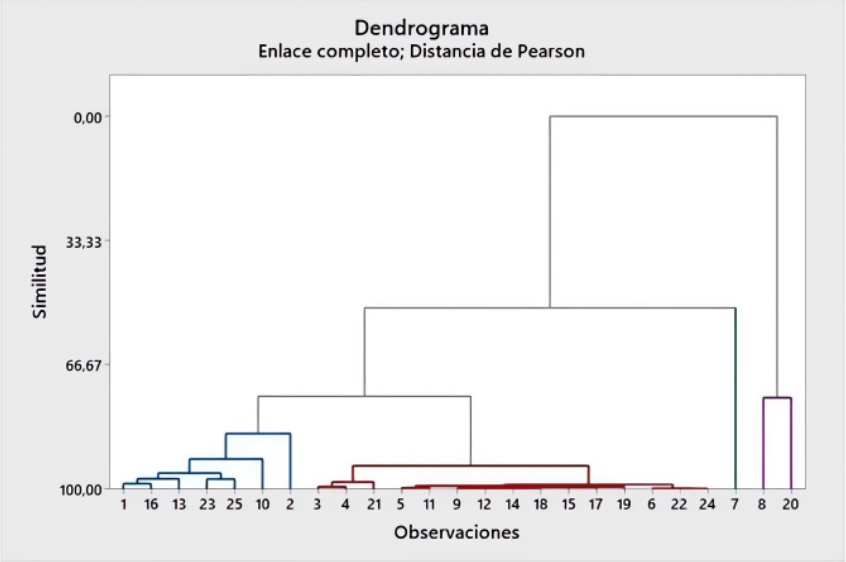

Figure 3. Dendogram full link analysis and Pearson's distance of financial information of banking establishments in the period 2016-2021.

Table I. Group centroids

Variable	Conglomerate1	Conglomerate2	Conglomerate3	Conglomerate4	Principal centroid
ACT 1	29654437	3716586	93548017	168876238	27785213
ACT 2	31575144	3950378	100771288	176656668	29374652
ACT 3	34225238	4063664	110723938	191708064	31786868
ACT 4	35926003	4457780	122222023	205553847	34067138
ACT 5	37701740	4930359	136413365	231918445	37524713
ACT 6	42868380	5594537	152680500	261094972	42354686
PAS 1	26607949	3156865	83502970	148982415	24603057
PAS2	28417856	3367750	89887422	155336783	26000089
PAS3	30857560	3432799	99314042	168546564	28156083
PAS4	32387779	3785576	109571124	180221036	30140452
PAS5	34256444	4229885	123639364	206611538	33604233
PAS6	39269511	4872232	138400682	231462758	37971850
PATRI1	3046489	559721	10045047	19893823	3182157
PATRI2	3157287	582634	10883866	21319886	3374566
PATRI3	3367678	630865	11409896	23161500	3630785
PATRI4	3538224	672204	12650899	25332811	3926686
PATRI5	3444753	700475	12720001	25306907	3918168
PATRI6	3598869	722305	14279818	29632214	4382836

In a focused examination of the 25 banks that reported to the Financial Superintendence of Colombia over the five-year span from 2016 to 2021, the research presents a detailed breakdown of how these establishments are distributed across the identified groups or clusters. Utilizing a color-coded system to visualize this distribution, the study's findings can be described as follows: The first profile, represented in blue, comprises seven banking establishments. This suggests that this particular group captures a unique set of characteristics shared among these seven institutions. Given that they constitute a substantial portion of the total, it implies the presence of common practices or operational features that might be prevalent in the sector.

The second profile, indicated by the color red, is the largest cluster with 15 banking establishments. This cluster's sizeable count suggests that a significant portion of the sector falls under a shared set of financial, regulatory, or operational parameters, making it an especially important focus for stakeholders interested in understanding broad trends or implementing sector-wide initiatives. Contrastingly, the third profile, denoted by the color green, contains just a single banking establishment. This outlier might represent an institution that operates under unique circumstances, making it distinct from the broader trends in the sector. This singular observation merits further scrutiny, as it could reveal valuable insights into specialized or niche areas of the banking landscape. Lastly, the fourth profile is represented by the color purple and consists of two banking establishments. Although small in number, this cluster hints at another subset of banks

that share specific characteristics, but are differentiated enough from the other profiles to warrant their own separate category.

This distribution across different color-coded profiles reveals a complex, multi-layered landscape within the Colombian banking sector. It not only underscores the diversity of operational models but also emphasizes the need for nuanced approaches in regulatory oversight, policy development, and strategic planning. The delineated groups or clusters, characterized by varying numbers of observations, offer a structured way to understand the complexities of the sector, thereby providing a roadmap for future research and decision-making. as shown in Figure 3 and table I. The average distance from the centroid is 34,616,644.

Table II. Average and maximum distance from centroid

	Number of observations	Within the sum of squares of the cluster	Average distance from centroid	Maximum distance from centroid
Conglomerate1	7	1,39652E+16	35511237	99606724
Conglomerate2	15	3,59589E+15	12020941	351605591
Conglomerate3	1	0,00000E+00	0	0
Conglomerate4	2	1,65381E+16	90934398	90934398

Regarding the analysis of the level of heterogeneity between groups, the calculation of the distances between the centroids of the four conglomerates of the financial information of the banking establishments that report to the Superintendency of Finance was carried out. Table II shows the average distances between the conglomerates with an average of 381855377, which is greater than the average distance from the centroids, which is representative of the level of discrimination of the financial information of these establishments, as can be seen in the table III.

Table III. Distance of centroids between clusters

	Conglomerate1	Conglomerate2	Conglomerate3	Conglomerate4
Conglomerate1	0	103324375	282673226	566150474
Conglomerate2	103324375	0	385756816	669308198
Conglomerate3	282673226	385756816	0	283919174
Conglomerate4	566150474	669308198	283919174	0

Discriminant Analysis

In the scholarly work discriminant analysis is delineated as a subcategory of multivariate analysis, serving as a classification technique that can be applied to one or multiple data sets [37]. The primary utility of this methodology lies in its ability to facilitate more effective differentiation among various groups under examination. Specifically, discriminant analysis enables the identification of meaningful disparities in the profiles corresponding

to score distributions across a predefined set of variables stipulated in the research study. This analytical approach thus offers a rigorous and nuanced tool for researchers aiming to categorize or cluster subjects, items, or phenomena based on a suite of quantitative metrics.

The overarching objective is to discern significant differences that may exist among the groups under scrutiny. Through the application of discriminant analysis, one can achieve greater statistical precision in classifying entities within the dataset, thereby unearthing subtleties that might otherwise elude more rudimentary forms of analysis.

By empowering researchers to more accurately identify and interpret differences among varying groups, discriminant analysis becomes an invaluable asset in both academic and applied research settings. Its capability to deal with multiple variables simultaneously while aiming to categorize them makes it a robust and versatile methodology suitable for a wide array of disciplines and study objectives.

Based on the above, the discriminant analysis was performed taking into account the identified variables such as: Assets (ACT), Liabilities (PAS), Equity (PATRI), Income (ING) and Result for the year (RESUL), of the financial information of the banking establishments that reported information to the financial superintendence of Colombia, said analysis was performed through the SPSS Statistics software, then the fulfillment of the assumptions required to apply the (ADM) was verified and the objective function was calculated to analyze the financial information of the banking establishments.

Table IV. Case processing summary

Cases					
Valid		Lost		Total	
N	%	N	%	N	%
25	100,00%	0	0,00%	25	100,00%

The table IV provides a summary of the number of valid cases, in the present investigation the 25 banking establishments present valid information corresponding to 100% of the information.

Table V. Box M test results

M de Box	151,581
F Aprox.	6,548
gl1	15
gl2	527,072
Sig.	0,00

As can be seen in Table V, the result of the contrast statistic M= 151.581 with F= 6.548 and with an associated probability p-value= 0, where if the p-value is less than 0.05,

the equality between the matrices is rejected, that is to say that there are differences between the groups. The result of the test of the present investigation allows rejecting the equality of variance-covariance matrices, considering that (Sig. 0.00 < 0.05), therefore, it can be concluded that the groups have different variance-covariance matrix.

Table VI. Eigenvalues and percentage variance

Function	Eigenvalue	% variance	% accumulated	Canonical correlation
1	0,294a	100	100	0,477

The information from table VI on the study conducted, it is posited that eigenvalues serve as a robust metric for evaluating the distribution of intergroup dispersion [37]. Unlike some statistical measures, eigenvalues possess a minimum value of zero, while lacking a predefined upper limit. Due to this characteristic absence of a maximum boundary, the Wilks' Lambda statistic is frequently employed as a conventional alternative for comparative analyses.

In the context under consideration, an eigenvalue of 0.294 was derived, situating it at the lower end of the spectrum, particularly when restricted to a range between 0 and 1. This low eigenvalue suggests a minimal level of intergroup variability within the dataset. Conversely, the canonical correlation value, another important statistic, was found to be moderate at 0.477. This value falls below the arithmetic mean, indicating that the strength of the relationship between the sets of variables under study is neither extremely strong nor extremely weak. The combination of these two statistics—eigenvalue and canonical correlation—provides a comprehensive understanding of the data's intergroup dispersion and the correlational relationships therein.

Table VII. Wilks Lambda Test

Contrast of functions	lambda de Wilks	Chi-square	gl	Sig.
1	0,773	5,281	5	0,383

According to the information from table VII, the Wilks' Lambda overall significance test statistic is moderately high (0.773), indicating that there is considerable overlap between the groups. This finding is supported by the Lambda transformed value (Chi-square = 5.281), associated with 5 degrees of freedom, a significance level of 0.383 which leads to accepting the null hypothesis of equality of means [p-value = 0.383 > 0.05], suggesting then, that this function is not significant and, consequently, the null hypothesis that the groups are equal is accepted.

Conclusions

The process of cluster analysis allows concluding that there are acceptable levels in terms of intra-group homogeneity and extra-group heterogeneity, for which the Minitab

software was used with complete linkage grouping criteria and Pearson's distance as a measure of similarity. In this sense the dispersion analysis of the data was performed, considering pertinent to establish 4 conglomerate groups, which correspond to the financial management profiles of Banking establishments that reported to the Financial Superintendence in the period 2016-2021, the first profile is observed with 7 observations, the second profile with the highest number of observations 15, the third profile with one (1) observation and finally the fourth profile with two (2) observations. The average distance from the centroid is 34,616,644.

Regarding the discriminant analysis, the result of the contrast statistic through Box's M test was found that M= 151.581 with F= 6.548 and with an associated probability p-value= 0, the result of the test of the present investigation allows rejecting the equality of variance-covariance matrices taking into account that (Sig. 0.00 < 0.05), therefore, it can be concluded that the groups have different variance-covariance matrix. Similarly, by means of Wilks' Lambda test, the results lead to accepting the null hypothesis of equality of means [p-value = 0.383 > 0.05], which suggests that this function is not significant; consequently, the null hypothesis that the groups are equal is accepted.

Finally, it managed to evidence that the financing of the banking sector in Colombia presents uniform average levels of indebtedness and autonomy, for the data analyzed in the time series, 2016, 2017, 2018, 2019, 2020 and 2021, the behavior and performance were reasonably proven at 89% and 11%, respectively. It should be noted that regardless of the economic recession in 2020, the relative levels of the financial position indicators remained stable.

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