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Impact of the COVID-19 Pandemic on Sales Across Economic Sectors: A Canonical Biplot Analysis in Milagro, Ecuador

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Abstract The article provides a detailed analysis of sales in the San Francisco de Milagro canton during the period 2017-2023, focusing on economic resilience in the face of the COVID-19 pandemic. Using data from the Internal Revenue Service and the International Standard Industrial Classification, the main economic sectors are identified, and their evolution over time is analyzed. Distinctive patterns in sales are observed, highlighting the impact of the pandemic on sectors such as Commerce and Agriculture. Computational experiments were conducted using MultBiplot v18.0312 statistical software to apply Canonical Biplot, which offers a graphical visualization of the relationships between sectors and years. The results reveal complex patterns, underscoring the importance of promoting trade and agriculture to ensure long-term economic stability in Ecuador.
JEL codes: C38, J01.

Key words: Sales, economic resilience, COVID-19 pandemic, Canonical Biplot

1 Introduction

At the heart of every community lies a key indicator of its economic vitality: the total sales. This indicator not only reveals the commercial pulse of a region but also unveils its growth potential, challenges, and opportunities. Each recorded transac-

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tion echoes the commercial activity defining the identity of a canton. By reflecting a community's economic health, total sales point the way towards a more prosperous and sustainable future (Liu et al., 2020; Chen et al., 2021).

We believe that sales analysis has become an invaluable tool for urban planners, entrepreneurs, and community leaders, providing crucial insights into local dynamics and guiding strategic decisions (Smith & Williams, 2022). In this context, we argue that Multivariate Statistics emerge as a robust approach to unravel complex patterns and interdependent relationships in economic data (Hair et al., 2021). For instance, the challenges faced by the gig economy and Fairwork in Ecuador, in our view, highlight the complexities and regulatory gaps that can impact economic activities and labor conditions (Albornoz & Chavez, 2024).

Milagro is a city with approximately 204,917 inhabitants, located in the province of Guayas, Ecuador, about 40 minutes from the city of Guayaquil. The economy of Milagro is primarily characterized by the following sectors: agriculture, particularly the cultivation of sugar cane; commerce; manufacturing; and services (INEC, 2022). During the period 2017-2023, the canton of San Francisco de Milagro has experienced significant changes in its economic structure, influenced by both local and global factors. Analyzing gross sales across various economic sectors allows us to identify these changes and understand the forces driving them. In particular, the COVID-19 pandemic has had a profound and lasting impact on local and global economies, altering consumption and production patterns (Zhou et al., 2023). The severe impact on SMEs in Santa Elena serves as a pertinent example of how economic segments can be deeply affected by global crises (Calderón et al., 2024).

We contend that the use of multivariate analysis techniques, such as principal component analysis and cluster analysis, allows for the exploration of relationships between different economic and sectoral variables (Johnson & Wichern, 2022). These techniques, we believe, provide a comprehensive view of how various economic sectors interact and respond to external shocks, such as the pandemic (Martínez et al., 2022).

Besides the pandemic, other factors such as globalization, digitalization, and governmental policies have also influenced sales in the canton of Milagro. For example, we observe that digitalization has accelerated e-commerce, changing the dynamics of retail and wholesale sales (Davis et al., 2021). This shift has created both opportunities and challenges for local businesses, which must adapt to new ways of interacting with consumers (Williams & Brown, 2021).

The government policies, both at the national and local levels, have played a crucial role in mitigating the economic effects of the pandemic. Measures such as fiscal stimuli and support programs for small and medium-sized enterprises have been fundamental in sustaining economic activity during the most critical periods (Fernández & García, 2021). We believe that the effectiveness of these policies can be evaluated through the detailed analysis of sales in different economic sectors (Smith et al., 2021).

This study focuses on a detailed multivariate analysis of gross sales in various economic sectors of the canton of San Francisco de Milagro during the period 2017-2023. Through this approach, we examine the behaviors of these sectors at different

stages: before, during, and after the impact of the COVID-19 pandemic. We argue that the findings provide valuable insights into the resilience and adaptability of the local economy in times of challenge (González & Martínez, 2023).

To achieve this, a comprehensive methodological framework was established. First, data were collected from the Internal Revenue Service (Servicio de Rentas Internas, SRI), covering the period from 2017 to 2023. Subsequently, a multivariate statistical technique, including Canonical Biplot, was employed. These technique enabled the exploration of complex interrelationships between different economic sectors and the identification of underlying patterns in the sales data. The computational experiments were conducted using the MultBiplot v18.0312 statistical software, leveraging its robust capabilities for statistical analysis and data visualization.

Economic resilience, in our view, refers to an economy's ability to absorb shocks and recover quickly. In the context of Milagro, it is crucial to understand how different sectors have shown resilience or vulnerability to sudden changes (Kaufman & Scott, 2022). We assert that this knowledge is essential for developing strategies that strengthen responsiveness to future crises (Miller et al., 2021).

We believe this research offers a solid foundation for informed decision-making that drives the sustainable economic development of the canton. By understanding sales dynamics and sectoral interactions, planners and policymakers can design more effective interventions aligned with local needs (Chen & Lee, 2022). This approach, in our opinion, not only enhances economic resilience but also promotes inclusive and sustainable growth.

2 Materials and Methods

2.1 Database Construction

Using the open databases provided by the Internal Revenue Service (Servicio de Rentas Internas, SRI), accessible on the official website https://www.sri.gob.ec/web/intersri/datasets, information corresponding to the gross sales of the canton Milagro was downloaded, covering the period from 2017 to 2023.

Gross sales represent the sum of the values of net sales at 0% and 12%, as recorded by the SRI. Additionally, the various economic sectors considered have been coded according to the International Standard Industrial Classification (ISIC) 4.0 of the National Institute of Statistics and Censuses (INEC) from 2012. The details of this classification are presented in Table 1.

The original datasets include multiple variables, but for this analysis, we extracted the data related to sales in Milagro. The total size of the concatenated dataset is approximately 347,539 records with 14 variables each year. The specific variables are AÑO, MES, CODIGO_SECTOR_N1, PROVINCIA, CANTON, VENTAS_NETAS_TARIFA_12, VENTAS_NETAS_TARIFA_0, EXPORTACIONES, COMPRAS_NETAS_TARIFA_12, COMPRAS_NETAS_TARIFA_0, IMPORTACIONES,

Table 1 *National Classification of Economic Activities according to ISIC 4.0*

Code	Economic Sector
A	Agriculture, forestry, fishing and hunting
B	Mining and quarrying
C	Manufacturing industries
D	Electricity, gas, steam and air conditioning supply
E	Water supply; sewerage, waste management and remediation activities
F	Construction
G	Wholesale and retail trade; repair of motor vehicles and motorcycles
H	Transportation and storage
I	Accommodation and food service activities
J	Information and communication
K	Financial and insurance activities
L	Real estate activities
M	Professional, scientific and technical activities
N	Administrative and support service activities
O	Public administration and defense; compulsory social security
P	Education
Q	Human health and social work activities
R	Arts, entertainment and recreation
S	Other service activities
T	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use
U	Activities of extraterritorial organizations and bodies

COMPRAS_RISE, TOTAL_COMPRAS, TOTAL_VENTAS. For this study, the chosen variables were: AÑO, MES, CODIGO_SECTOR, and TOTAL_VENTAS.

2.2 Statistical Analysis and Visualization

For the statistical analysis, we employed multivariate techniques such as Canonical Biplot to explore relationships between economic sectors and identify underlying patterns in the data. These analyses were performed using the MultBiplot v18.0312 statistical software for generating biplots.

A flow diagram of the data analysis process is provided in Fig. 1. This diagram outlines each step from data extraction to the final analysis and visualization, ensuring that the methodology is transparent and replicable.

2.3 Biplot Methods

Biplots, as described by Gabriel (1971) and subsequently detailed by Gabriel et al. (1990), are a graphical representation of multivariate data in which three or more variables are represented together. This allows for the representation, in a reduced-

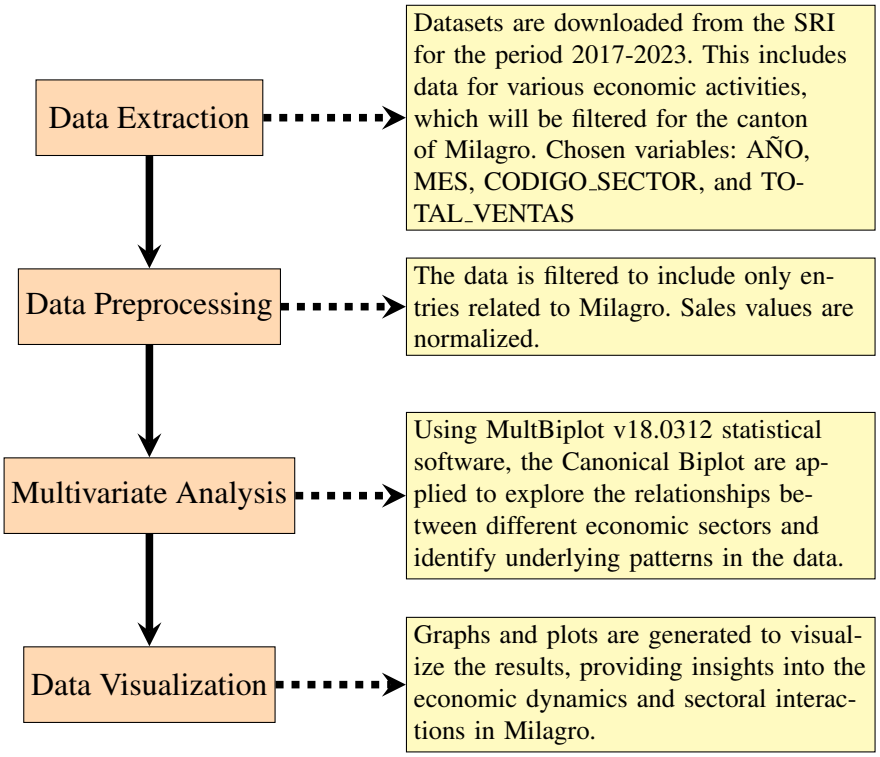

Fig. 1 *Flow diagram of the data analysis process from extraction to visualization.*

dimensional space, of both subjects and variables in the form of vectors onto which subjects can be orthogonally projected to interpret their value in each of those variables.

According to Galindo et al. (1999), the Biplots proposed by Gabriel allow for the representation of data from an $X_{n\times p}$ matrix (n-individuals $\times$ p-variables) in a reduced-dimensional space, simply by choosing markers $a_1, a_2, \ldots, a_n$ for its rows and $b_1, b_2, \ldots, b_p$ for its columns, such that the inner product $a_i^T b_j$ reproduces the element x_{ij} of the matrix X.

Using the singular value decomposition of matrix X:

$$X = UDV^T$$

where U is the matrix of eigenvectors of XX^T, V is the matrix of eigenvectors of X^TX, and D is a diagonal matrix formed by the singular values of X. X can be written as $X = AB^T$ by choosing matrices A and B as $A = UD^\alpha$ and $B = VD^{1-\alpha}$, where α is a parameter that can take different values; for example, if $\alpha = 0$, it results in the GH-Biplot representation, in which only the variables are well represented, and if $\alpha = 1$, the JK-Biplot representation, in which only the individuals are well represented (Gabriel, 1971; Gabriel et al., 1986). Referring to being well represented

corresponds to saying that in the Biplot graph, there is a good approximation; the approximation is given by the dimensionality reduction such as Principal Component Analysis (PCA) (Jolliffe, 2002).

As a particular case, taking $A = UD$ and $B = VD$ as markers, the HJ-Biplot representation is obtained (Galindo, 1985, 1986; Galindo et al., 1986); which, in his publication, Galindo achieves the maximum quality of representation for both individuals and variables. Interpreting the results of Biplots involves considering the angles between vectors representing variables and the factorial axes, indicating the characteristic elements of those axes. Moreover, the angles between vectors show the correlation between indicators or the covariance between variables, with proximity indicating high correlation and perpendicularity indicating independence.

The length of the vectors representing the variables provides information about the discriminative capacity between individuals and the variability of the variable, with greater lengths indicating greater variability. The distance between individuals reflects the degree of similarity between them in relation to the measured variables.

2.4 Canonical Biplot

Canonical Biplot, also known as MANOVA-Biplot, introduced by Vicente Villardón (1992) and developed by Amaro et al. (2004), is a type of Biplot in which pre-defined subject groups are represented separately with maximum discriminant power between them, projecting the mean matrices. This approach, in addition to providing a descriptive analysis, allows for inferences to be made by representing prediction regions (confidence intervals) of the group means on the graph. These regions are circular, as the distances in the Euclidean space of the graph approximate the Mahalanobis distances in the original space.

The distinctiveness of this technique lies in its ability to visualize the directions of maximum variability of the study groups, in this case, over the years (Amaro, et al., 2004). Furthermore, the Canonical Biplot applies a dimensionality reduction of the data through singular value decomposition. These values not only indicate the percentage of absorbed variability but also offer a measure of the data representation quality in the Biplot graph (Gower, 1966). This deep and detailed approach allows for a more comprehensive understanding of the economic dynamics at play, providing valuable insights for strategic decision-making and policies.

According to Varas et al. (2005), consider that the n rows of the data matrix X are divided into k groups, where each group has n_k individuals. This matrix X is centralized or standardized by columns. Consider X as the matrix that includes the means of each group for each variable present in it; additionally, let D_n be the diagonal matrix showing the sizes of the groups, and let W and B be the matrices of covariance within and between groups, respectively; that is:

$$W = \frac{1}{(n-k)}(X^T X - X^T D_n X)$$

$$B = \frac{1}{(k-1)}(X^T D_n X)$$

To obtain a Biplot representation in which the groups are separated with maximum discriminant power between them, the matrix is constructed as follows:

$$Y = PDQ^T$$

and the singular value matrix can be used to calculate a Biplot representation of Y, where P and Q are orthogonal matrices containing the singular vectors and D is the diagonal matrix containing the singular values in decreasing order (Johnson & Wichern, 2007). From this equation, the JK, GH, and HJ Canonical Biplot can be obtained (Fang & Zhang, 2004).

The graphical interpretation of the Canonical Biplot follows the same principles as the standard representation of Biplots but also includes confidence intervals of the group means (centroids), allowing for the identification of significant differences between groups (Escabias & Valderrama, 2010). The Canonical Biplot representation goes further by not only visualizing the distribution of the groups and their relationships with the variables but also by incorporating confidence intervals of the group means (centroids) (Greenacre, 2010). These intervals allow for the orthogonal projection of confidence regions onto the variables of interest, thus facilitating the identification of significant differences between groups based on their behavior in those specific variables (Martínez de la Vega, 2001).

By observing the overlap or separation of these confidence intervals on relevant variables, conclusions can be inferred about the statistical significance of the differences between groups in terms of those variables (Lawley, 1959). This approach enriches the interpretation of the Canonical Biplot by providing a deeper understanding of the data structure and the relationships between groups in a multivariate space (Jöreskog & Sorbom, 1993; Yee & Hastie, 2003).

3 Results

Among the various economic sectors with records in the Internal Revenue Service (IRS) of transactions in the city of Milagro during the period from 2017 to 2023, the following stand out: *Wholesale and Retail Trade* (G), *Agriculture, Livestock, Forestry, and Fishing* (A), *Manufacturing Industries* (C), *Transportation and Storage* (H), and *Professional, Scientific, and Technical Activities* (M), in that order, as evidenced in Fig. 2.

These sectors, being fundamental pillars of the local economy, play a crucial role in the development and economic dynamics of the city of Milagro. A detailed understanding of their trends and behavior patterns is essential for formulating effective strategies for sustainable growth and development.

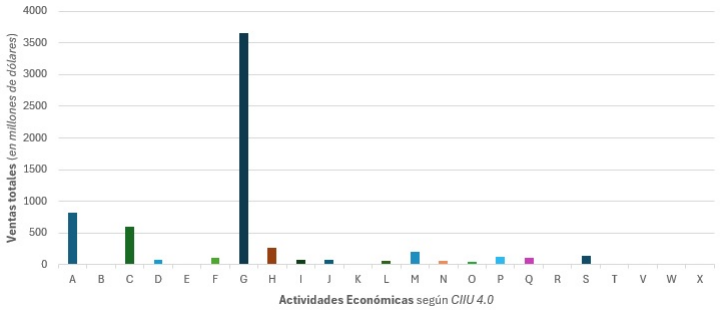

Fig. 2 *Total sales of economic activities from January 2017 to December 2023.*

Observing the evolution of the top 5 economic sectors during the study period, as represented in Fig. 3, distinctive patterns reflecting the effects of the Covid-19 pandemic can be identified. For instance, the *Wholesale and Retail Trade* sector experienced significant growth in the years leading up to the pandemic (2017-2019) but suffered a notable decline during the lockdown period, reflecting the direct impact of sales restrictions. However, as restrictions eased, this sector began to gradually recover, only to face challenges again in the post-pandemic period, possibly associated with security concerns. Meanwhile, other sectors maintained relative stability, showing an ability to resist and adapt to economic fluctuations and changing external conditions. This observation underscores the importance of a deeper understanding of the data through advanced analytical tools, such as Canonical Biplot, to capture the complexity and interrelationships between economic sectors in the overall landscape.

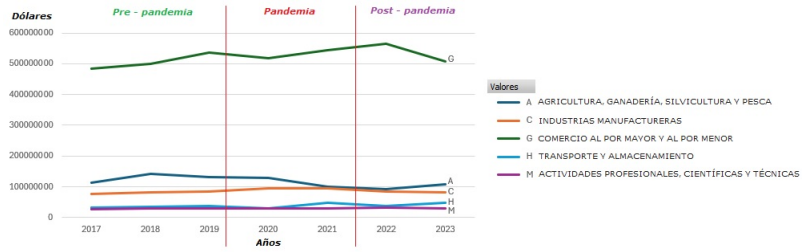

Fig. 3 *Total sales of main economic activities from January 2017 to December 2023.*

After conducting a descriptive study of the data, we proceed to enrich the analysis by applying a powerful tool: the Canonical Biplot (Villardón, 1992). This multivariate analysis technique, belonging to the family of Biplots, uses vectors on a plane to represent the variables (in this case, the Economic Sectors) and points to represent the individuals (the months). The above descriptions provide an initial glimpse into the presented economic information, allowing for a superficial analysis of this

economic indicator during the study period in the city of Milagro. However, by employing Canonical Biplot, the door is opened to a deeper and more meaningful exploration. This graphical technique offers a richer and more detailed visual representation, going beyond simple figures. Through Canonical Biplot, complex patterns can be discerned, relationships between variables identified, and a better understanding of the economic dynamics of the study area achieved. Instead of being confined to isolated data points, this tool provides a holistic view, allowing for a more comprehensive and contextualized understanding of Milagro's economic information.

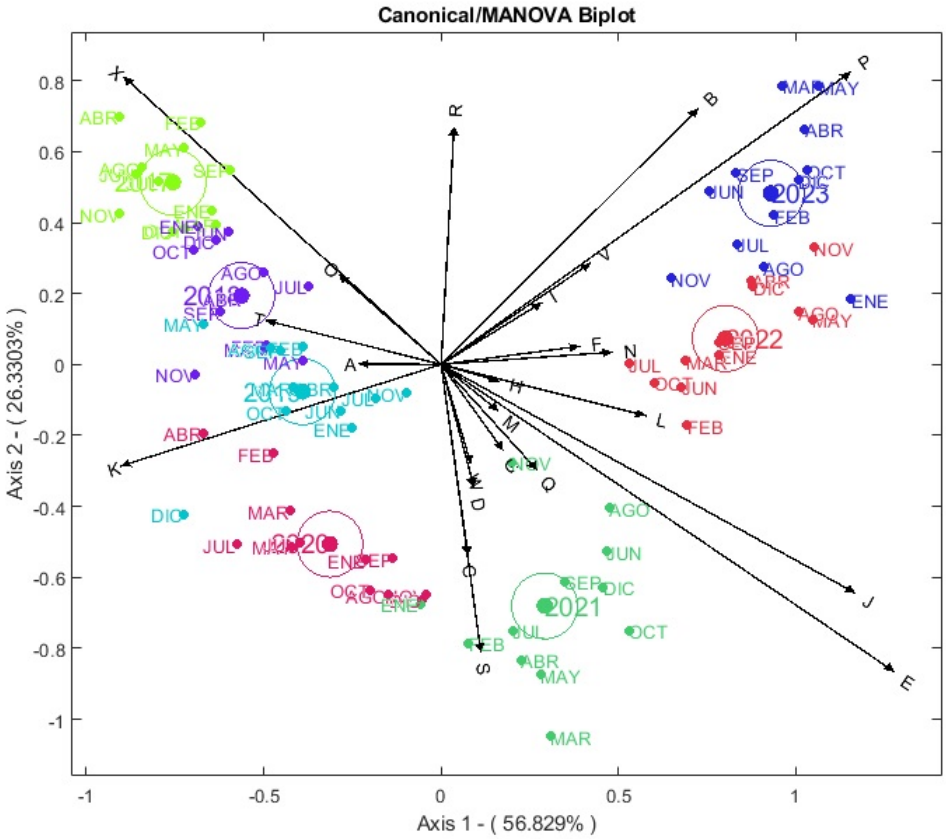

Fig. 4 *Canonical Biplot of one-way Net Sales of the city of Milagro during the period 2017-2023.*

Fig. 4 shows the graphical result of the *Canonical Biplot* or also known as *MANOVA - Biplot*, obtained from the *MultBiplot v18.0312* software. As this technique is based on dimensionality reduction, it can be observed that approximately 83.16% of the information or variability of the analyzed data is retained on axes 1 and 2, this result is relatively high to indicate the quality of representation of the

Economic Sectors and study years. The confidence circles of each group (years) are perfectly separated, which will allow for the identification of differences in group means. The details of the eigenvalues obtained, their variance, and their cumulative variance are shown in Table 2.

Table 2 *Eigenvalues and Explained Variance*

Dimension	Eigenvalue	Explained Variance
1	4.03	56.83%
2	2.75	26.33%
3	1.66	9.60%

In the Biplot graph, variables (economic sectors) are represented by vectors (arrows), indicating the direction of growth.

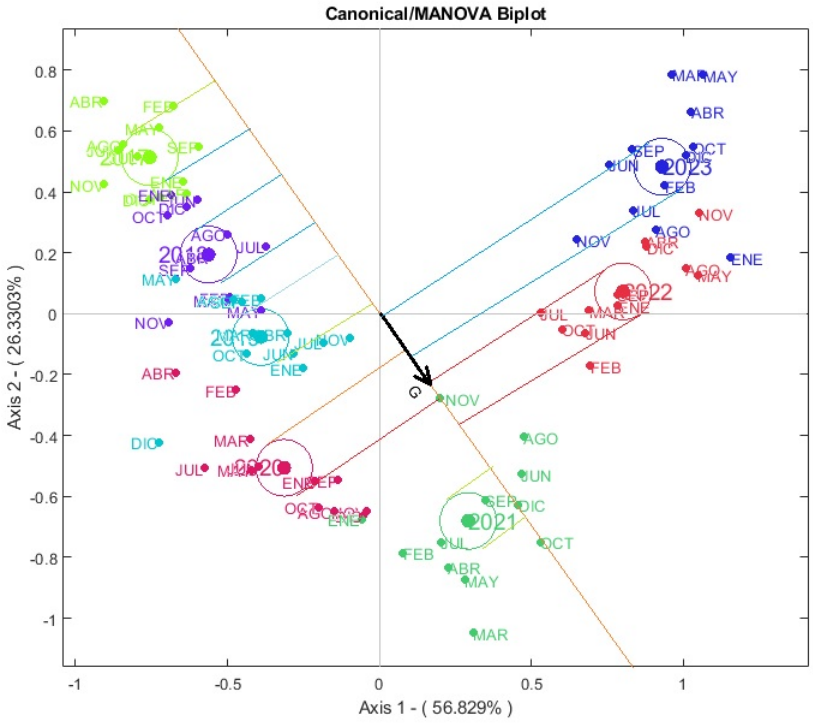

Fig. 5 *Confidence regions of the Canonical Biplot projected onto sector G.*

According to Fig. 5, considering the first economic sector, *Wholesale and Retail Trade (G)*, in the city of Milagro during the study period, orthogonal univariate projections of the confidence circles of each group are carried out; for example, it can

be observed that in the year 2021 (*green-colored group*), there are high contributions towards this sector, followed by the years 2022, 2020, and 2023, in that order.

This allows for an analysis that in the years following the pandemic, this sector economically reactivated; conversely, in the years 2017, 2018, and 2019, before the pandemic, sales contributions to this sector were lower.

As an additional detail, crossings can be observed between the projected regions of the years 2020 with 2022 and 2020 with 2023, suggesting that the years 2022 and 2023 had similar behaviors to the pandemic period; that is, although this sector reactivated in 2021, its contribution diminished in the following years, possibly due to an unconsidered variable like insecurity. Similarly, in the economic sector of *Agriculture, Livestock, Forestry, and Fishing (A)*, identified as the second economic sector in the city of Milagro, it is observed that the year with the highest sales contribution is the year 2017, and as time has passed, contributions to this sector have decreased year after year.

From another perspective, but based on the same Canonical Biplot graph, before the pandemic; that is, in the years 2017, 2018, and 2019, Milagro's sales focused more on sectors A, O, K, and T, for example; in the midst of the pandemic, in 2020, sales focused on sectors K, A, T, S, C, and D; and after the pandemic on sectors E, J, L, Q, M, H, F, N, S, D, and G.

To provide a clear and comprehensive overview of the findings, Table 3 summarizes the key results observed in the study. The table not only highlights the significant patterns in the sales data across different sectors but also emphasizes the impacts of the COVID-19 pandemic and other external factors, while connecting these findings to relevant theoretical frameworks.

Table 3 *Summary of Key Results and Theoretical Connections*

Sector	**Key Findings**	**Theoretical Connection**
Wholesale and Retail Trade (G)	This sector experienced significant growth in the pre-pandemic years (2017-2019), indicating strong economic activity. However, there was a notable decline during the pandemic (2020), reflecting the direct impact of lockdowns and reduced consumer spending. Post-pandemic (2021-2023), the sector showed partial recovery with fluctuations likely due to ongoing security concerns and shifts in consumer behavior towards online shopping.	Business Cycle Theory (Schumpeter, 1939); Consumer Behavior Theory (Kotler, 2000)
Agriculture, Livestock, Forestry, and Fishing (A)	The highest sales contributions were recorded in 2017, with a steady decline observed in subsequent years. The sector showed resilience during the pandemic, maintaining moderate activity levels, but did not recover to pre-pandemic levels. Factors such as supply chain disruptions and changes in demand patterns influenced this trend.	Resilience Theory (Holling, 1973); Supply Chain Management (Mentzer, 2001)
Manufacturing Industries (C)	Maintained relative stability throughout the study period, showing moderate growth and resilience even during the pandemic. This stability suggests effective adaptation strategies within the sector, including automation and diversified supply chains.	Industrial Organization (Porter, 1980); Adaptation Theory (Nelson & Winter, 1982)
Transportation and Storage (H)	Exhibited a stable trend with minor fluctuations over the study period, indicating a high level of adaptability to external conditions including the pandemic. The sector's stability was supported by the essential nature of transportation services and adjustments in logistics operations.	Logistics and Supply Chain Theory (Ballou, 2004); Essential Services Framework (Noll, 2000)
Professional, Scientific, and Technical Activities (M)	Showed consistent performance with minimal impacts from the pandemic, reflecting stable demand for professional services. This sector benefited from the increased reliance on remote work and digital services during and after the pandemic.	Remote Work Theory (Hill et al., 1998); Digital Economy (Tapscott, 1996)
Information and Communication (J)	This sector showed significant growth, particularly during the pandemic, as businesses and individuals increasingly relied on digital communication and information services. The trend is expected to continue as digital transformation becomes more entrenched in business operations and daily life.	Information Society Theory (Castells, 1996); Technology Adoption (Rogers, 2003)
Accommodation and Food Service Activities (I)	One of the most affected sectors during the pandemic, experiencing severe declines in 2020 due to lockdowns and travel restrictions. However, there was a notable rebound post-pandemic, driven by pent-up demand and the gradual reopening of the economy.	Hospitality Management Theory (Lashley, 2000); Crisis Management (Mitroff, 2004)

4 Conclusions

The canton of San Francisco de Milagro experienced a revival in certain key sectors such as Wholesale and Retail Trade and Agriculture, Livestock, Forestry, and Fishing after the initial impact of the COVID-19 pandemic. This recovery, however, was followed by a decrease in economic contributions in subsequent years, possibly due to unobservable variables.

Before the pandemic, the sales distribution in Milagro was influenced by established buying patterns and consumer preferences. The COVID-19 outbreak brought drastic changes in consumer behavior, driven by mobility restrictions, social distancing, and health concerns. This led to a decrease in economic activity and shifts in purchasing preferences, such as an increased inclination towards online shopping and prioritizing essential products. As the health situation stabilizes and restrictions are relaxed, some of these changes are likely to persist in the long term, impacting business strategies and the economy overall.

The use of tools such as the Canonical Biplot has provided a deeper and more contextualized understanding of the economic dynamics in Milagro. These tools have allowed for the identification of complex patterns and relationships between variables that would not be evident through traditional analysis.

Ecuador emphasizes the importance of promoting both trade and agriculture while diversifying the range of products offered. These initiatives reflect a strong commitment to comprehensive economic development and the pursuit of greater stability and sustainable growth for both the local and national economy.

By boosting trade, Ecuador expands its commercial horizons and consolidates its position on the international stage while strengthening its ties with other nations. The promotion of agriculture and the diversification of product offerings not only strengthen the country's economic resilience but also promote food security, generate employment, and foster rural development. In a world characterized by uncertainty and volatility, investing in agriculture and diversifying production becomes a fundamental strategy to ensure the stability and sustainable growth of the Ecuadorian economy.

The methodology employed in this study, which includes data preprocessing, multivariate analysis using Canonical Biplot, and robust data visualization techniques, provides a structured approach to analyzing complex economic data. This methodology can be beneficial for other researchers aiming to analyze similar datasets and understand economic dynamics in different contexts.

Future research could explore the use of different statistical models and techniques to analyze the same data, such as factor analysis, cluster analysis, or the use of principal components. Additionally, further studies could investigate the impact of other variables, such as government policies or technological advancements, on the economic sectors of Milagro. Comparing the results of these different approaches could provide a more comprehensive understanding of the economic resilience and adaptability of the region.

By addressing these aspects, the study not only contributes to the existing body of knowledge but also provides a framework for future research that can enhance

our understanding of economic dynamics in the face of crises like the COVID-19 pandemic.

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